THE EFFECTS OF METACOGNITIVE SKILLS TRAINING ON HANDS-ON LEARNING FROM SCIENCE OBJECTS

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1996

DEDICATED TO

Jeanne M. Donnelly
and
Scott, Meredith and Matthew Keeran

ACKNOWLEDGEMENTS

It gives me great pleasure to express my sincere appreciation to my committee members: John J. Koran, Jr., Chairman, Mary Lou Koran, David Miller, Eugene Todd, and Edward Turner for their guidance, advice, and encouragement throughout this study. I would also like to thank Mary Kantowski, Chairperson of the Department of Curriculum and Instruction, for her support at a critical time of this project. Gordon Greenwood and John Bengston provided valuable help in recruiting volunteers for this study.

Special thanks go to Maureen Bonner and Sherry Poole who provided important logistical support. Meredith Marvel contributed her expertise by producing the graphics for this report. My friend and colleague Betty Camp assisted and advised me on many occasions in many ways throughout the study. My family, Scott, Meredith and Matthew Keeran gave me the time and support to allow me to complete the study. And finally, I thank my mother, Jeanne M. Donnelly, whose total confidence, prodding and encouragement made this project possible.

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Abstract of Dissertation Presented to the Graduate
School of the University of Florida in Partial
Fulfillment of the Requirements for the Degree of
Doctor of Philosophy

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By

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December 1996

Chairperson: John J. Koran, Jr.
Major Department: Instruction and Curriculum

This study investigated the efficacy of a metacognitive training program designed to assist students in learning from science objects. The purpose of this study were (1) to identify strategies that would allow students to become aware and control their thinking about objects; (2) to incorporate these strategies into a metacognitive training program; (3) to examine the effectiveness of this training program; and (4) to explore the interaction of learner characteristics with the effectiveness of the training program.

An eight-step, object-learning metacognitive training program was developed. The training program consisted of written directions and a practice activity. This program was tested with 122 undergraduate students from a large public university in Florida. Subjects were randomly assigned to one of four treatment groups in a posttest-only control group experimental design and were given aptitude tests of induction, visual memory, and verbal ability to investigate possible interactions between these aptitudes and object learning.

One significant effect (p<.05) indicated that subjects who participated in the application task performed better on a test of science basic skills, concept knowledge, and metacognitive knowledge than students who did not experience the activity. Also, an aptitude x treatment interaction was significant (p=0.04). Subjects who scored low on the induction aptitude measure performed best on the application task when they had the opportunity to participate in the training program first. Subjects who scored high on the induction measure performed best on the application task when they did not participate in the training program first. The training program provided needed support to students who scored lower in induction, while interfering with the high ability subjects. Interestingly, verbal ability and visual memory did not predict performance or interact on this task. The finding that the training program was effective for certain students when measured by the application task score

could be a result of a match between the training program content (skills) and the method used to assess these skills.

CHAPTER 1
INTRODUCTION

Science educators have long been encouraged to plan extensive hands-on experiences for their students as a way to more effectively meet science education goals. Piaget (1969) described the needs of concrete operational students to engage in these types of activities. Dewey's hands-on learning (1938) and Bruner's inductive learning model (1959) also emphasized this approach. Osborne and Wittrock (1967) proposed that students actively "generate" meaning from hands-on experiences mediated by prior knowledge and memory. The post-Sputnik explosion of science curriculum reform resulted in a variety of programs which all relied heavily on hands-on activities including Science-A Process Approach (SAPA), Science Curriculum Improvement Study (SCIS) which incorporated the learning cycle model, and the Elementary Science Study (ESS) (see Martin, Sexton, Wagner & Gerlovich, 1994, for a complete description of these programs). Constructivist theory has heavily influenced new science curriculum proposals (Science For All Students, 1993) and here too students are characterized as learners actively constructing knowledge from experience. The teacher's role is that of a facilitator, providing experiences which allow students to carry out these investigations. According to Yore and Craig (1992, p. 1), constructivist theory "dominates science conferences . . ." Hands-on activities are critical to these types of programs as well.

There has been controversy concerning the effectiveness of programs which emphasize hands-on activities. Shymansky (1989) and Bredderman (1982) analyzed ESS, SCIS, and SAPA and reported positive cognitive and affective results of these programs. The issue here was comparing the new curriculum to existing curriculum which had different objectives, therefore little evidence of the direct benefits of a hands-on approach was generated. In discussing discovery learning approaches, which emphasize student construction of knowledge, Pressley, Snyder, and Cariglia-Bullet (1987, p. 90) noted a "lack of evidence that the method is effective!" and in a scathing comment regarding the usefulness of discovery methods they note that "one of the real hallmarks of human intelligence is that tools can be passed from generation to generation, eliminating needless, slow, and uncertain reinventions." (Pressley et al., 1987, p. 90). Novak (personal communication, 1995) concluded that hands-on discovery activities are not effective without guidance.

Pilot investigations conducted by the author with preservice elementary school teachers clearly indicated that even college students who participated in hands-on science activities designed for use in the elementary school classroom had difficulty acquiring the intended scientific concept illustrated by the activities. Completing the activity was no guarantee that conceptual knowledge was acquired.

These observations are supported in the literature. In observations of students working on a computer program that allowed students to discover how to use the computer to solve problems, some students were satisfied giving indiscriminate instructions simply to produce changes on the screen (Linn, 1986). They were content with the action and did not acquire the specific skills desired. Schauble, Klopfer, and Kalyani (1991, p. 867) also pointed out that while doing activities, students "confuse understanding relationships with producing effects." They engage in activities and remember the effect "without understanding."

Watson and Konicek (1990) concurred that hands-on activities alone are not sufficient to produce conceptual change. A recent study of 43 elementary school teachers exposed to Newtonian mechanics hands-on activities clearly indicated that exposure to the activities alone did not guarantee cognitive gains (Ledbetter, 1995).

It may not be a failure of hands-on activity oriented programs themselves but the learners ability to effectively learn from these experiences. In instances where hands-on activities have not been effective in concept learning, it may be that students were not adequately instructed in how to use objects in concept learning. Science educators have coined the phrase "hands-on, minds-on learning" to emphasize that manipulation of objects alone is insufficient for concept learning (Martin et al., 1994, p. xv). The question becomes, how can teachers help students achieve the "minds-on" component of object learning?

Background to the Problem

Metacognitive research may offer a solution to the problem of how to improve learning from hands-on objects. For the purposes of this study, metacognition is defined as the "awareness and control individuals have over their cognitive processes" (Baker, 1991, p. 2). To date, the field of metacognition has primarily focused on how to teach students how to learn effectively from written materials. Reading specialists have recognized the need to train students in effective comprehension strategies. An extensive literature has developed supporting the notion that you must not only teach content, but you should also teach students strategies to evaluate, monitor and improve understanding. These strategies teach students how to learn and encourage the development of independent learners.

The majority of these studies have been conducted with narrative text. A smaller number of studies have examined the differences between narrative and expository text and the implications of these differences with respect to strategy training for learning from science texts (Craig & Yore, 1992; DiGisi & Yore, 1992). There has been little activity regarding the issue of metacognitive training specific to learning from hands-on science activities. According to Rohwer and Thomas (1989, p. 126) there is a need for "accepted instructional design principles for specifying how the acquisition of metacognitive and domain-specific knowledge can be effectively fostered."
In a study of sixteen elementary age students who were required to experiment with two different hands-on activities, children were often asked to make predictions and justify their conclusions by being asked "What did you learn?" and "How do you know?" (Schauble et al., 1991, p. 879). They noted that students do not automatically ask these questions of themselves. These are metacognitive evaluative questions and they improve the students performance, but students do not do this type of metacognitive regulation on their own. Schauble et al. (1991, p. 879) concluded that children will only develop

acceptable methods of scientific inquiry if they are given practice and support. Children initially attempted to produce desired results, but over the series of sessions, began to discover the principles and rules that governed the tasks. The researchers felt that this shift could only occur when the students became aware that the task required it. Metacognitive training could improve this awareness.

Linn (1986) called discovery learning the "potentially best approach for helping students gain metareasoning skills and deep understanding . . . students get practice in selecting approaches to problems. They often get feedback showing that their approaches are unsuccessful, and they then seek a different approach until they find a solution to the problem . . . They experience the process of generating alternatives, and testing again." (Linn, 1986, p. 183). Discovery alone was insufficient, however. She found that although students could use metareasoning skills to "discover" the failure of their solutions, they did not spontaneously use the metareasoning skill of testing their solution and responding appropriately to the feedback. She concluded that unless discovery learning is coupled with metareasoning instruction, learning may not take place. On the other hand, she pointed out that discovery learning combined with metareasoning training could result in autonomous learners.

Appropriate metacognitive skills necessary for learning from hands-on objects in the science classroom have not been described in the literature. The purpose of this study was to extend metacogitive training studies to the context of learning from science objects at an elementary science class level.

Purpose

The purposes of this study were (a) to develop a metacognitive strategy training program that is designed specifically for hands-on science activities, (b) to examine the effects of this metacognitive training program on concept acquisition, (c) to examine the effects of this metacognitive training program on metacognitive knowledge, and (d) to investigate the interaction of learner characteristics with the effectiveness of the training program.

Definition of Selected Terms

For the purposes of this study, the following terms are defined:

Aptitude is any characteristic of an individual which acts selectively with respect to learning (Cronbach & Snow, 1977).

Hands-on activities are activities that allow the student to manipulate an object or objects and to experience it with multiple senses.

Induction is the ability to discover rules that explain things (Ekstrom et al., 1990, p. 79).

Inference is an extension of an observation that serves to explain what is observed, to classify or generalize (Kauchan & Eggen, 1980).

Metacognition is the awareness and control individuals have over their cognitive processes (Baker, 1991).

Metacognitive training program is a written program instructing students to follow a series of steps that are designed to increase students' awareness and regulation of their cognition.

Observations are datum collected using the five senses (Kauchak & Eggen, 1980).

Verbal ability is the ability to understand the English language (Ekstrom et al., 1990, p. 163).

Visual memory is the ability to remember the configural, location, and orientation of figural materials (Ekstrom et al., 1990, p. 109).

Importance of the Study

In spite of the trend towards the constructivist philosophy of teaching in science teacher training programs and the emphasis on hands-on activities for elementary science learning, there are still serious questions concerning the effectiveness of such activities. Science educators can take a cue from researchers who have realized that students need to learn how to learn from text before they can effectively learn from texts, and recognize that when students do not learn from hands-on activities, it may not be a failure of the activities themselves, but rather a failure to provide students with the metacognitive tools to make productive use of the activities

Brown, Bransford, Ferrara, and Campione (1983) describe several steps of theory development. The first step is a "goal-oriented" stage of theory testing. The second stage is a definition and testing of discrete issues encompassed by the theory. The final stage occurs when there is enough information about the components of the theory to again consider it as a whole. They believe that the study of metacognition is in the second stage, of refining the theory in all of its contexts. The present study will help extend metacognitive theory in this second stage by testing it in the context of hands-on science activities.

Summary

Pressley, Forest-Pressley, Elliott-Faust, and Miller (1985) called for new strategies which are devised to meet the challenges of education today. This study sought to elucidate appropriate strategies for learning from science activities and determine what types of learners these strategies were most effective for. Also it provided information concerning the effectiveness of training on concept acquisition.

CHAPTER 2
LITERATURE REVIEW

There are several areas of the research literature that contribute to the questions addressed in this study. The general literature defining metacognition can provide a foundation for further studies. Reading comprehension training research offers suggestions regarding specific strategies identified to be of use in learning in one context. Special issues in adult metacognitive training and the implications for teacher training are addressed. The literature regarding context-specific training and metacognitive studies in science content also provides additional direction. Museum research in learning from objects and the roles of attention and curiosity in object learning offer strategies that can be adapted to classroom applications. Finally, aptitude treatment interactions are explored in order to determine if the metacognitive training program developed would be effective for different types of learners.

Metacognition Defined

For over 20 years, researchers have shown an interest in the awareness that students have of their own learning. Flavell (1977) called metamemory knowledge about memory.

He described it as having two components, sensitivity and knowledge of the variables that affect memory performance, including strategy variables. Novak (1984) referred to metaknowledge and metalearning. Metaknowledge refers to knowledge about the production and structure of knowledge. Metalearning is learning about learning. Linn (1986, p. 155) discussed metareasoning as "the ability to reason about one's reasoning."

According to Campione, Brown, and Connell (1989), there has been a confusion in the literature regarding what metacognition actually means. Campione et al. (1989) reviewed the literature and identified two distinct yet interrelated components of metacognition, a student's knowledge about cognition and a student's self-regulation of cognition.

The various definitions of metacognition conceptualize it as a two-fold construct, one being some type of an awareness of cognition and the other an ability to regulate cognition (Baker, 1991). For the purposes of this study, this two-component definition of metacognition will be adopted. Metacognition is the "awareness and control individuals have over their cognitive processes" (Baker, 1991, p. 2). Both awareness and control features have been included in the metacognitive training program.

According to Haller, Child, and Walberg (1988, p. 6), "Although the essence of metacognition is still being debated, there seems to be more agreement about the mental activities it comprises: awareness, monitoring, and regulating functions to aid faltering understanding." Metacognitive training studies are concerned with helping students monitor their own learning, choose strategies appropriate to the task and use those strategies. Baker (1991, p. 3) included "planning our moves, checking the outcomes of our efforts, evaluating the effectiveness of our actions and remediating any difficulties, and testing and revising our learning techniques" as among metacognitive regulation strategies.

The metacognitive studies of interest here are those which define strategies appropriate to a learning task and then devise training programs to teach children these strategies. These studies will help elucidate what features are critical to the success of a metacognitive training program.

Metacognition and Reading Comprehension

The vast majority of metacognitive training studies examine reading comprehension strategies. Paris and Jacobs (1984) referred to metacognitive skills as reading awareness. They conducted a four-month-long study which consisted of teaching 91 third graders a sequence of lessons called informed strategies for learning. The goal of informed strategy instruction is "to convince children that there are many reasonable actions to take while reading and that the extra effort required will result in improved comprehension" (Paris & Jacobs, 1984, p. 2084). This study found significant correlations between reading awareness and reading comprehension. They concluded that this type of training in reading awareness benefitted children of all levels of awareness and that classroom instruction can improve students' ability to use reading strategies (Paris & Jacobs, 1984, p. 2091).

Haller et al. (1988) described typical comprehension monitoring activities including self-questioning, paraphrasing, summarizing, integrating prior knowledge with content information, comparing main ideas, confirming assumptions and making predictions. Regulating activities are rereading, searching, contrasting textual information with prior knowledge, and comparing main ideas.

The literature supports the conclusion that training studies have demonstrated that it is possible to improve students use of reading comprehension metacognitive strategies. Haller et al. (1988) conducted a meta-analysis of 20 experimental studies testing metacognitive training in comprehension. This analysis confirmed that metacognitive training is effective in improving reading comprehension.

They concluded that the effects of training seem to be greater for older children and that training benefitted lower achieving readers more. They also determined that effective training required more than 10 minutes of instruction per session and reinforcement, and that several instructional modes is preferable to few.

There are three components of strategy instruction that relate to declarative, procedural and conditional knowledge. Declarative knowledge of strategy use encompasses what a given strategy is. Procedural knowledge represents how to use strategies, while conditional knowledge involves when and why to use them (Paris & Byrnes, 1989). The effectiveness of metacognitive strategy training programs when students are trained beyond the declarative knowledge stage is well documented in the literature. In an early training study, Brown and Barclay (1979) demonstrated that strategy instruction produced significant differences in strategy use with a group of mildly retarded eleven-year-old children if the instruction included information not only of what strategies to use (declararive knowledge) but also how, when and why (procedural and conditional knowledge) the strategies should be employed. This is referred to as informed instruction by Brown and Barclay (1979) concluded that to be successful, training needed to include not only information concerning what strategies to use, but also the when and why of strategy use.

A model of informed strategy instruction proposed by Palinscar and Brown (1989, p. 31) included six steps:

1. identifying the strategy
2. explaining why the strategy is being taught
3. demonstrating the strategy
4. guiding students' acquisition and application of the strategy
5. explaining when the strategy would be useful
6. informing students how to evaluate the effectiveness of using the strategy and what to do if the strategy has not been effective

Ghatala (1986) reviewed the research concerning the connection between strategy-utility knowledge and effective strategy maintenance and selection. She concluded that strategy instruction is effective when presented along with instruction on how to monitor the effectiveness of a given strategy. Strategy monitoring activities involve asking the following questions; "Is the present strategy working? Is the material being comprehended? Is it being remembered?" (Ghatala, 1986, p. 45).

The importance of providing students with explicit strategy instruction is further highlighted by Balajthy (1988) who pointed out that readers use their existing knowledge to interpret what they read, and that these interpretations can be wrong. Furthermore, as children do not spontaneously develop strategy-utility knowledge and monitoring skills, it is necessary to equip them with these abilities through explicit training. Pearson and Dole (1987) also determined that the effectiveness of an explicit instruction model is well documented in the literature.

Metacognitive research has sought to document what strategies are appropriate for a given task and to determine how to best teach those strategies. In the context of text comprehension, Brown, Campione, and Day (1981) described a tetrahedral model of learning from text that they adapted from a learning model of Jenkins (1979). The four variables which interact in the learning of text are the characteristics of the learner, learning activities, nature of the materials and criterial tasks (Brown et al., 1981, p. 19). According to Brown et al. (1981), up until the 1980's, research on text reading focused on the nature of the materials, which included text structure, cohesion, logical content, and cues. They believed there was a need for additional research into criterial tasks and learning activities such as strategies and monitoring. Learning activities are characterized as either general or specific.

Summarization is an example of a specific strategy and general strategies include "generating hypothesis about the text, predicting outcomes, noting and remediating confusions," (Brown et al., 1981, p. 19)

Other researchers have delineated strategies to improve text comprehension. Strategies enumerated by Pressley et al. (1985) included the following:

- overview materials
- question oneself about text headings
- retrieve from memory everything one knows about the topic
- examine sample questions
- rereading
- deploying more attention to problem areas
- recite/review

Derry and Murphy (1986) believe appropriate text comprehension strategies vary with the type of text. Their list describing categories of strategies is as follows:

- encoding: naming, rehearsing, elaborating generative: paraphrasing, visualizing,
- inferencing, summarizing, using prior knowledge to help determine text
- constructive: reasoning, transformation, synthesis

In a comprehensive review of the literature, Palincsar and Brown (1989, p. 20) concluded that there were six reading comprehension strategies:

- clarifying the purposes of reading to determine the appropriate approach
- activating background knowledge
- allocating attention to the major content
- evaluating for internal consistency and compatibility with prior knowledge and common sense
- using monitoring strategies for comprehension
- drawing inferences and testing them

Levin (1986) listed 9 learning strategies necessary for reading comprehension; activating prior knowledge, skimming,asking questions,mapping,paraphrasing,imaging, note taking, reviewing, and summarizing. He believed that there was a need for empirical validation of which strategies are most effective.

This review of the strategies that were shown to be effective in the studies examined above indicate several which are common to many of the programs, and which may be useful in an object learning training program. These include activating prior knowledge, reviewing (rereading), evaluating for consistency and drawing inferences. Furthermore, it was critical to the success of these studies that students were provided with both procedural and declarative knowledge of the strategies. Although presented in the context of reading comprehension, these features suggest strategies that can be tested in the context of object learning.

Metacognition and Content

The literature reviewed to this point involved reading comprehension strategies since the bulk of the metacognitive training research has been in this area. To what extent are these strategies general and applicable across different content areas? Do reading comprehension strategies relate to science education? These questions will effect the generalizability of much of the reading comprehension metacognition research. Are there learning strategies that are general and appropriate in a variety of subject areas (Brown et al, 1983; Campione et al., 1989), or are they content specific?. These issues were raised by Pearson and Dole (1987). According to Perkins and Salomon (1989), most metacognition studies have not addressed matching context specific knowledge with general strategies, and there is a need for more research into this issue.

Baker (1991) and Padilla, Muth, and Lund Padilla (1991) pointed out that there was a close correspondence between metacognitive reading skills and science process skills.

Teaching science processes may then have a positive effect on reading and metacognitive skills. Carin and Sund (1989) describe similarities between reading skills and those used in discovery science activities. This parallel between metacognitive skills and science process skills suggests that the literature on reading comprehension metacognitive skills may shed some light on appropriate skills training for science activities.

Many researchers believe, however, that strategies for learning are highly dependent on the content of the discipline. Volet (1991) believes appropriate strategies should be derived from expert behavior in a specific content area. Rohwer and Thomas (1989) assert that the structure of content knowledge is domain specific and that this must be paired with content-specific metacognitive knowledge. They believe that students are not given the experiences necessary for them to acquire knowledge structures and strategies consistent with expert performance. (Rohwer & Thomas, 1989, p. 115). Garner (1990, p. 5180) pointed out that "weak strategies in one domain may be powerful strategies in another." She highlighted the importance of context to strategy use and believed that strategies may be domain specific.

In the context of mathematical problem solving, Schoenfeld (1989, p. 86) discussed that knowledge is "contextually bound" and that knowledge about a particular domain is "shaped by the practices of those domains." Therefore, metacognitive strategies would be distinctive to a particular domain. Lester (1989) agreed that relevant metacognitive activities are related to domain-specific knowledge.

Brown and Palincsar (1985, as reported in Pearson and Dole, 1987) developed a reciprocal teaching method in which four reading strategies were taught, explained and modeled by an expert. Instruction was designed to allow students to gradually become independent users of these strategies. In this study, these strategies were taught using content area textbooks. Significant, long-term improvements in reading comprehension scores were achieved with poor readers. Also, these same students significantly improved in their performance on tests in other domains including science and social studies. As pointed out by Perkins and Salomon (1989), this can either be interpreted to be evidence that transfer did occur (across school subjects) or that it is not evidence of transfer because they were all reading tasks.

According to Perkins and Salomon (1989), this issue of the relative importance of general strategies versus content-dependent expertise has been studied by psychologists for 30 years. A review of the discussion led them to propose that what was needed was a synthesis of the two positions, one that recognized the importance of general cognitive skills while at the same time acknowledging the importance of domain-specific skills. They referred to this as a "contextualization through a knowledge base" (Perkins and Salomon, 1989, p. 19)

The literature supports the conclusion that it is appropriate to look at domain-specific metacognitive strategies while at the same time acknowledging that some general strategies may be useful. While the reading comprehension studies provided valuable insights into what types of strategies may be useful across subjects, the literature reviewed above indicates it is also appropriate to investigate context-specific strategies. Therefore, metacognitive issues discussed in the context of science learning are reviewed below.

Metacognition and Learning from Science Texts

The literature on metacognitive strategies in the context of science learning is small. One area that may provide insights into science context-specific strategies that has received attention is science learning from texts. Given the initial emphasis on metacognition and reading comprehension, it is not surprising that researchers have become interested in metacognition and learning from science texts. Craig and Yore (1992) discussed the fact that reading comprehension research has primarily centered on narrative texts. However, expository science texts require processing different from that necessary for narrative texts. Problems with science texts that hinder comprehension include an over-reliance on low-level questions and insufficient explanations (Holliday, 1991), and lack of congruence between textbook material and science education goals (Finley, 1991). The researchers noted that students are more proficient at comprehending narrative text and there was a need for better training in expository text comprehension.

Otero and Campanario (1990, p. 447) identify "learning by reading" as the primary technique for learning elementary school science. DiGisi and Yore (1992) noted that students in fourth grade are faced with greater conceptual demands as they move from narrative to expository text, and that they are not sufficiently trained in how to make this switch effectively. This may be due to a lack of understanding, on the part of teachers, of the differences between narrative and expository text.

Shymansky, Yore, and Good (1991) studied teacher beliefs about science texts with 522 K-8 teachers. They found that elementary school teachers did not view science text reading as different from narrative material. They identified some strategies necessary to improve comprehension of science text including engaging prior knowledge and using generative processes "to search, analyze, and explain the ideas in the text . . ." (Shymansky et al., 1991, p. 452). Shymansky et al. (1991) call for improved teacher training in the area of strategies for science text reading.

A study of 532 fourth through eighth graders concluded that middle school students have "limited" knowledge concerning strategies for reading science texts (Yore & Craig, 1992). While other studies have shown that metacognitive awareness for narrative text increases with grade level, this was not found to be the case for science texts. Yore & Craig, 1992 developed criteria for strategies specific to science text reading comprehension that emphasize that:

- reading is an interactive process
- science text is not the absolute truth
- science texts have a unique structure
- words are labels for ideas
- strategies must be used to recognize and distinguish fact from opinion and beliefs
- strategies must be selected for specific tasks

These studies support the assertion that there are differences in strategy instruction based on context and that these differences do require attention to science-context specific strategies, in addition to general comprehension strategies.

Metacognition and Non-Science Text Materials

Yore and Craig (1992) refer to metacognition, in the context of science education, as "an umbrella construct that has gained popularity within the science education community while its relationship to cognitive styles, self-managed explorations and science learning remains fuzzy" (Yore & Craig, 1992, p. 2). The research concerning metacognition and non-text science materials is meager (Groslight,Unger, Jay, & Smith, 1991). Rohwer and Thomas (1989) acknowledged that the research needed to identify basic metacognitive training techniques has been conducted primarily with mathematics and physical science content.

The need for an examination of what strategies are appropriate for science materials is highlighted by a study of 153 middle school students which looked at the students' beliefs about science and how those beliefs affected the student's ability to integrate knowledge (Songer & Linn, 1991). The students were divided into three groups according to their beliefs: static (science as facts to be memorized), dynamic (scientific ideas change and the best way to learn them is to learn how they are related), and mixed (both beliefs). Only 15% of the students belonged to the dynamic beliefs group, and this is the group that was best able to acquire integrated knowledge. Songer and Linn (1991, p. 782) believe that "Unless students look jointly at knowledge generation and the outcomes of the knowledge generation process, they are unlikely to develop an integrated, productive understanding of science or of science concepts."

Mergendoller, Marchman, Mitman, and Packer (1988) studied the level of cognitive demands made on 7th grade students by life science materials used by eleven different teachers. They assessed level of cognitive demands of the materials because "The types of thinking students engage in and the quality of learning that occurs are largely influenced by the nature of the tasks students complete" (Mergendoller et al., 1988, p. 251). The researcher analyzed 31 lab activities, 45 worksheets, and 31 exams. These materials emphasized low-level skills. Of particular interest is the finding that all of the labs employed simple, step-by-step directions and many teachers assigned labs in which not only the problem and procedure were explained, but the solutions as well were delineated. Labs were limited and accompanying worksheets required short, primarily descriptive answers. Mergendoller et al. (1988. p. 258) concluded that most of the "elements typically viewed as an integral part of the laboratory experience of scientific thinking" were absent from these year-long programs. Of particular significance was the fact that students were only rarely given a reason for completing the labs. Both the Songer and Linn (1991) study and the Mergendoller et al. (1988) study illustrate that students are not being exposed to the types of activities that would enable them to acquire scientific knowledge structures and processes that are characteristic of the scientific domain.

Scientists have different methods of problem solving than students (Larkin & Chabay, 1989; Schauble et al., 1991). Reif and Larkin (1991) contrasted the differences in the goals and cognitive strategies used in everyday life and in science. They contend that students have difficulty learning science when they don't recognize these differences and rely on everyday goals. In everyday life adequate prediction and explanation suffices while science strives for optimum prediction and explanation. Adequate precision and consistency satisfies everyday goals, but maximal precision and consistency are required in science. Scientists make many inferences and assessing validity is of prime importance to them. In everyday life people make fewer inferences and assessing validity is only of moderate importance. There are also differences in the domain cognition areas of knowledge structures, methods and quality concerns.

These differences imply domain specific metacognitive strategies. It also illustrates the need to clearly identify domain specific goals. Reif and Larkin (1991) conclude that students should be explicitly instructed about the goals and the thought processes of science and that they should be taught in the context of actual science courses. They also believe that teachers are not sufficiently informed about the differences and the implications of these differences for instruction.

Evidence that children do not automatically acquire scientific cognitive strategies is provided by Schauble et al., (1991). In agreement with Reif and Larkin (1991), Schauble et al. (1991) also believe that students rely on everyday methods of inquiry which differ from scientific methods. When presented with a problem, children tend to search incompletely and unsystematically, fail to control extraneous variables, distort evidence that is inconsistent with their preconceptions, and make logical errors (Schauble & Glaser, 1990). They also do not exhibit metacognitive awareness of the requirements of an experimental task and tend to stop too soon.

Of interest to the current study, 16 fifth and sixth graders were read a description of how scientists approach an experimental problem (Schauble et al., 1991). The students then worked on an experimental task over three 40 minute sessions. Students showed improvement, as measured by the number of valid inferences, over the sessions. Throughout the work sessions, students were repeatedly asked questions that required them to make predictions and explain their conclusions. The researchers noted that "Students do not spontaneously ask these questions of themselves, and there is scant opportunity in the classroom to practice these skills and to consider these questions" (Schauble et al., 1991, p. 879). They conclude that students must be given practice and support in order to acquire scientific modes of inquiry. The implication of this study for instruction is that teachers need to recognize that students may approach an experimental situation without the necessary domain specific strategies to conduct the activity.

This research highlights the need for students to participate in activities that emphasize process skills, that differences between scientific and everyday goals must be addressed, that students must be encouraged to search completely and that practice is required. These are science-context specific issues that can be included in strategies for learning from science objects.

Preconceived Notions and Metacognitive Training

It is well documented in the literature that students come into a science learning situation with a personal store of previously acquired concepts about science and that these are often misconceptions that are extremely resistent to change (Grffiths, Thomey, Cooke, & Normore, 1988; Lawson, 1988; Philips, 1991; Posner, Strike, Hewson, & Gertzog, 1982; Simpson & Marek, 1988; Zoller, 1990). Of interest to the present study are several reports directly relevant to the development of metacognitive strategies for science activities.

Children construct their own scientific beliefs from everyday experience (Osborne & Wittrock, 1967). Osborne and Wittrock (1967) recognized that students in a classroom situation may not generate the same purpose for a given activity as the teacher. Furthermore, according to these researchers, classroom science experiments may not encourage children to relate information stored in memory to new information, to construct knowledge and to evaluate this new knowledge. Watson and Konicek (1990) argued that reading and observing scientific materials was not enough to change what they referred to as alternate frameworks that students have. They further pointed out "that even hands-on activities allow such thinking to go undetected" (Watson & Konicek, 1990, p. 681). Therefore, they recommended using discrepant events to challenge these preconceived notions, followed by a new explanation and further testing.

DiGisi and Yore (1992) report that metacognitive strategy training is more effective for students in grades 7 and up. They note that this may be due in part to the fact that students in grade 5 or lower are more resistent to information that contradicts their preconceived notions.

The problem of learning from hands-on activities is complicated therefore by the existence of preconceived notions. Activating prior knowledge and reflecting on it at the completion of an hands-on activity will be incorporated into the training program to address this issue. This reflection step will encourage the explicit comparison between preconceived notions and actual experience.

Teacher Training and Metacognition

In spite of the literature concerning the success of comprehension strategies training programs and the fact that students do not spontaneously utilize learning strategies, researchers have found that metacognitive strategies are often not taught (Brown et al., 1983; Perkins & Salomon, 1989). In fact researchers have concluded that traditional educational practice, in which the students are not given information about why they should participate in particular activities, is far more common (Campione et al. 1989). They refer to this as blind instruction. Rohwer and Thomas (1989) reported that teachers may directly teach how to use a strategy, but not teach why they are useful. As discussed earlier, strategy training that does not fully inform the students will not be as effective. Shymansky, Yore, and Good (1991, p. 338) reported that "the promising work of reading researchers.... and the renewed interest in elementary school science have done little to change attitudes and practices among teachers, administrators, and university educators regarding science and reading instruction."

One study of 69 elementary school teachers found that teachers gave instruction in strategy use during only 2.8 % of the 300, 20 second intervals that were observed (Moley et al., 1986). Teachers provided informed instruction during only 1% of the intervals observed while 10% of the teachers neglected strategy instruction all together (Moley et al., 1986). They called for improved teacher training concerning the development of cognitive skills.

A study of 37 middle and secondary school teachers illustrated what the researchers called a "gap between research-derived knowledge and pedagogical practice" (Clift, Ghatala, & Naus, 1990, p. 254). They found that teachers rarely taught metacognitive strategies. Only 27% thought that students needed explicit strategy instruction. The majority of the teachers concentrated their efforts on teaching content. Only half of the teachers assessed strategy acquisition during the school year. Furthermore, teachers and researchers defined strategy differently, with teachers identifying "teacher-led activities for learning content such as flash cards" (Clift et al. 1990, p. 261) as strategies.

Clift et al. (1990) believe this gap between research findings and practice was due to several factors. First, the majority of these teachers believed that children acquire strategies on their own as they mature, from task structures or from teacher modeling. Lester (1989) perceived a need for additional research into teacher beliefs as related to metacognitive issues. Secondly, teachers may not have been trained in metacognitive strategies including the need for and the procedures for strategy training. The third explanation for this lack of incorporating metacognitive research into classroom practice is that many researchers conducting strategy instruction studies worked directly with students rather than teachers. Clift et al. (1990) and Rohwer and Thomas (1989) also emphasized the need to improve teacher training in this area. According to Balajthy (1988), for students to master metacognitive strategies, teachers must model these strategies. It is therefore imperative for teacher education to include instruction in explicit strategy instruction.

Most of the research on metacognitive training has been conducted with children. Levin (1986) pointed out that strategies that are effective for children may not be appropriate for adults. Of relevance to the issue of teacher training, an important exception is a study of college students enrolled in a computer science class. In this study, informed instruction included how to use the strategy and explanations and demonstrations regarding how, when and why to use the strategy (Volet, 1991). This instruction coupled the content of the subject with metacognitive skills relevant to that content. This training resulted in significant increases in both cognitive and affective outcomes.

Teacher training in metacognitive issues is particularly important given that the "effectiveness of an intervention program requires the commitment, enthusiasm and competence of the instructor" (Volet, 1991, p. 333). She believes that this is especially important for older students. Adult students must also be persuaded that the strategy is useful.

Pressley, Goodchild, Fleet, Zajchowski, and Evans, (1989) discussed what they referred to as obstacles to implementing strategy instruction in the classroom. They include inadequate teacher training, strategy instruction involves demanding teaching methods, there are a large number of strategies, transfer of strategy use is not automatic, individual differences in students, difficulties in monitoring performance and the lack of empirically tested strategy training materials.

There is agreement among these researchers that teacher training in metacognitive issues is lacking and that this results in failure to fully implement informed instruction in the classroom. These studies highlight the need for improved teacher training in metacognitive issues and provide further evidence that including the features of informed instruction is important when training adults as well as children. Given that many metacognitive studies have bypassed the teacher, the lack of strategy instruction observed in the classroom, and the lack of teachers' understanding of metacognitive strategy acquisition, it is appropriate to target preservice teachers as a study group.

Museum Research

Learning from Objects

Museum research offers insight into elements that might be applicable to strategies for object learning. Koran, Longino, and Shafer (1983) described museum exhibits along a continuum from static to dynamic. Static exhibits are case exhibits at which visitors play a passive role. Visitors process static exhibit information primarily through visual modes. Walk-through exhibits surround the visitor and often includes sound and can include smell. Dynamic exhibits are those that encourage active participation by the visitor and add the opportunity to touch or manipulate objects. Rice (1988, p. 146) believed that "touching as a way of making contact with the physical world is more basic than looking" and that "not touching is actually an unnatural thing to do." A group of museum professionals attended a workshop to discuss how people learn from objects. When presented with actual objects to study, "the urge to touch became overwhelming" (Porter & Martin, 1985, p. 37). They agreed that the "sensual exploration", including touching, smelling and hearing an object was basic to the learning process

As Koran et al. (1983) pointed out, each exhibit type has a classroom analog. Lectures, texts and bulletin boards correspond to static exhibits. Field trips correspond to walk-through exhibits. Dynamic exhibits are similar in design to hands-on activities and laboratory exercises. People comprehend objects mainly through the use of sight and touch (Pearce, 1992). Therefore, given the similarities between dynamic museum exhibits and hands-on classroom activities, museum exhibit research can provide insights into classroom activities that employ hands-on activities.

Goode, as quoted in Stapp (1984, p. 115) stated that "The museum cultivates the powers of observation . . ." Since observation is a basic process skill of primary importance to science learning, museum research can be of particular interest to the science educator.

According to Stapp (1984), schools teach students the necessary skills needed for library literacy, but no such training occurs for museum literacy. There is an incorrect presumption that people know how to learn from objects. Porter and Martin (1985) related that museums have assumed that visitors are able to learn from objects without understanding how it can occur. Stapp (1984) pointed out that museum literacy was equivalent to the ability to read objects, and that this can result only from education and practice.

Prown (1982) concurs that most people are "functionally illiterate" with respect to extracting meaning from objects. He described a three stage approach to objects. The student first describes the object by handling, using and experimenting with the object while drawing on prior experience. The next stage is interpretation of the interaction, and finally developing hypotheses and questions for testing.

A number of models for learning from objects have been proposed by museum researchers. Much of this work has been done in the context of art museums and with man-made objects. Williams (1984. p. 118) described the interest among museum researchers in museum literacy as a call for a "theory of instruction focused on teaching visitors how to have personally significant experiences with objects." She described 4 activities involved in learning from objects. The first is contemplation or "visual thinking". A feature of this stage, according to Williams, is the recognition that there are individual differences in how people perceive an object, that seeing is dependent upon focusing of attention, and that time, practice, and "freedom to explore" are necessary. The second step is reacting to the object, which is mediated by individual differences. Thinking about the object, and making judgments about it are the third and fourth steps.

The first two steps as described by Williams (1984) would apply to the observation of any type of object. Significantly, these steps recognize the importance of attention and the role of individual differences interacting with observations and reactions to objects, both factors of consequence in the process of constructing knowledge from a science object. She noted the application of metacognitive skills to museum learning by describing the role of an ideal museum tour as one which causes visitors to think about how they visually perceive, and she noted that this is a parallel to Jerome Bruner's metacognition.

Earlier, Fleming (1974) listed four steps that people use to interact with objects. The first step is identification, which includes classification and description (measurements and weight). The next step is evaluation, which involves comparisons with other objects. The third and fourth steps are cultural and functional analysis and interpretation, the purposes of which are to group according to "characteristics common to the group that enable the researcher to make inferences of a general nature" (Fleming, 1974, p. 9). The investigator evaluates the object to determine if it constitutes new evidence or if it confirms or contradicts existing evidence.

This type of evaluation would be as appropriate with science objects in that students could compare their observations and inferences with their existing knowledge and determine if it contradicts it or is providing new information. Fleming also recognized that different individuals will produce different interpretations.

The role of prior knowledge and the importance of the interaction of individual experiences when interpreting objects is well accepted in the museum literature (Pearce, 1992; Prown, 1982; Taborsky, 1990). According to Taborsky (1990, p. 62) "The knowledge which we have developed exists as a logical structure within which we make further observations, perceptions and then derive understanding." This view of how visitors extract meaning through an active process of interacting with the object coincides with the constructivist view of science learning that is popular in teacher training today.

Taborsky (1990) described two models of learning from objects, the discursive paradigm and the observation paradigm. The observation paradigm parallels the method traditionally used in science activities. In this model, the object is subjected to measurement, data collection, and "impartial observation", and the meaning derived from the object is the sum of these measurements. The discursive model acknowledges the importance of prior knowledge. In this model the importance of prior knowledge and naive notions is recognized in that meaning is derived through an interaction between the observer and the object. The failure of hands-on activities to produce conceptual change in the classroom may be due to the fact that the observation model is inadequate.

Finally, the need to train teachers in this area is discussed by Martinello and Gonzalez (1987). Unless teachers know how to learn from objects, they cannot adequately teach their students how to do so. They believe that museum learning requires skills in making connections between observations and prior knowledge. Of primary importance are observation skills and making inferences, and Martinello and Gonzalez conclude that teaching thinking skills in a museum is preferable to teaching content alone.

The models of learning from objects produced by the museum community can contribute to the development of a metacognitive training model for science learning from hands-on activities in the classroom. Initial exploration of an object, use of multiple senses, comparing to other objects, and evaluation are all steps in object learning in museums that can be applied to classroom science object learning.

Curiosity and Attention

A fundamental step in any learning process is attention (Bransford, 1979; Gagne, 1970). Museum research can provide information pertinent to this study concerning the role of attention and curiosity in science object learning. Museum educators have long recognized the importance of attention in exhibit effectiveness (Koran & Lehman, 1981; Shettel, 1973). In order for learning to occur from an exhibit, the exhibit must both attract and hold a visitor's attention (Koran & Koran, 1983; Shettel et al. 1968). These are referred to as attracting and holding power and both have been extensively studied (Hirshi & Screven, 1988; Peart, 1984; Screven, 1975; Shettel, 1973).

Holding power has been operationally defined by museum researchers as the total time spent at an exhibit or the time spent at an exhibit related to the time necessary to read the entire exhibit. Various factors influence the holding power of an exhibit, including the ability to manipulate it and the number of sensory channels the visitor can use to experience it (Koran et al, 1983). It has been determined that although dynamic exhibits have greater holding power that static exhibits, holding power measurements indicate a lack of sufficient attention across exhibit types (Hirshi & Screven, 1988; Koran et al., 1986; Peart, 1984).

It has also been shown that not only do students need to focus their attention on an object, they must focus on the relevant features of the object. Attention focusing devices that have been shown to be effective include the use of color, shapes, arrows and questions (Koran & Lehman, 1981). Finally, in a recent study regarding the role of interest and attention, it was shown that the length of attention was more critical to learning than interest (Foster & Koran, 1989).

The role that curiosity plays in attention with respect to learning from science objects is also appropriate to this discussion. Curiosity has been characterized in a dual role as both a response to a novel stimulus as well as a driving force in redirecting and focusing attention. This learning and memory model as described by Koran and Longino (1983) is illustrated in Figure 2-1. As shown in Figure 2-1, both attention and curiosity are pivotal to perception, coding, storage and retrieval of information. Curiosity is initially elicited by a novel object, and then proceeds to interact with attention and perception in the encoding of information. A lack of curiosity or attention would significantly affect learning from science objects.

The novelty and complexity of an object influences the curiosity elicited by an object. Generally speaking, the greater the novelty or complexity of the object, the higher degree of curiosity it will evoke (Koran & Longino, 1983). Just as time spent at an exhibit is utilized as a measure of attention, time spent in the vicinity of a stimulus is one type of measure of curiosity (Koran & Longino, 1983).

The practice activity included in this study provided the use of a sieve set, a novel piece of equipment to most people. The application task utilized actual biological specimens to evoke curiosity. The metacognitive training program included the use of questions to act as attention focusing devices. Bold lettering and highlighting of directions on the data sheets were also used to focus attention. These devices were designed to address the need to both evoke curiosity and maintain attention.

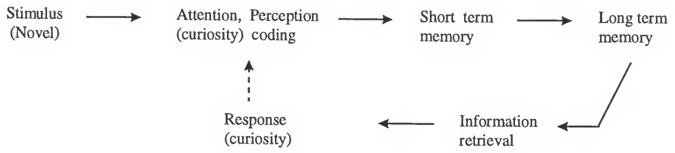

Figure 2-1. Learning and Memory Model (reproduced with permission from Koran and Longino, 1983, Fig. 1).

Aptitude-Treatment Interactions

Museum educators have recognized the importance of individual differences and the role they play in how people see and react to an object (Williams, 1984). Individual differences will affect how a learner reacts to a strategies training program. A successful strategies training program must specify the type of learner it is effective for. To determine this, aptitude-treatment interactions must be tested for. Aptitudes are characteristics of an individual that either facilitate or interfere with learning (Cronbach & Snow, 1977; Koran & Koran, 1984). They may influence how a student will respond to a particular educational environment. There are a wide variety of aptitudes including general ability, problem solving style, anxiety, memory abilities, logical reasoning ability, and conceptual level (Cronbach & Snow, 1977). A treatment is defined as any variable in the learning environment (Cronbach & Snow, 1977). Treatment variables include items such as pace, structure, type of instruction, sequence, and different curricula.

An aptitude-treatment interaction (ATI) is detected when students of different aptitudes perform differently when exposed to the same treatment (Cronbach & Snow, 1977). ATI research does not ask what type of learning environment is the best for all learners, but rather, which learning environment is best for which type of learner. The goal of ATI research is to identify optimum, individualized learning environments by matching particular environments with particular aptitudes.

In an extensive review of ATI research, Cronbach and Snow (1977) provided an overview of ATI studies published prior to 1977. They cited hundreds of studies which attempted to delineate how particular aptitudes interact with specific treatments. According to Smith and Sechrest (1991), ATI hypotheses need to be theoretically derived through a thorough analysis prior to the start of a study. The need for careful task analysis is highlighted by early ATI studies which looked at learning from visuals (graphs,diagrams, etc...) as compared to learning from text. Many researchers assumed that learning from pictorial representations would be related to spatial ability. For example, Allison (as cited in Cronbach & Snow, 1977) employed three aptitude measures of vocabulary and verbal reasoning as well as three spatial aptitude tests in a concept-attainment task study. Navy recruits were exposed to one of two concept-attainment treatments, one involving words or one involving shapes. The verbal presentations were easier for subjects scoring high on the verbal ability measures. The results did not support the conclusion that the shapes task was easier for those scoring higher in spatial ability.

A second study which tested the spatial/verbal ability dichotomy was conducted by Markle (as cited in Cronbach & Snow, 1977). High school students were given a measure of verbal ability and two spatial ability tests. They were given a presentation on crystallography which was presented either in words or in diagrams. Once again, the hypotheses that scoring higher on spatial ability would result in higher scores in the "spatial" treatment was rejected.

These results and additional studies caused Cronbach and Snow (1977) to question the validity of a verbal/spatial dichotomy. They concluded that the aptitudes necessary for a given treatment may not be a function of the characteristics of the stimuli itself. They suggested that the failure to show an interaction between these pictorial tasks and spatial ability is that although the tasks used pictures, they did not require spatial processing. They conclude that graphs and diagrams do not require spatial processing and therefore would not interact with spatial ability measures.

This points out the importance of examining processing requirements of a task, rather that stimuli characteristics. This approach is in agreement with Koran and Koran (1984) who point out that research which tested aptitudes based on

the similarity between task and treatment content has not produced ATI results. Koran (1974) emphasized the need to match task processing requirements with aptitudes.
For the purposes of this study, a analysis of the cognitive processing demands of the treatment tasks to be utilized was conducted. This led to a theoretically based selection of several aptitudes which may provide useful ATI information. The metacognitive training program and the task directions were presented in a written format. Additionally, when the task engages students in "classifying spatial material and generalizing a rule, verbal processes can be as important as spatial ones" (Cronbach & Snow, 1977, p. 281). The present study included the use of objects as well as written material, therefore it was appropriate to chose a measure of verbal ability. The Extended Range Vocabulary Test (Ekstrom, French, Harman, & Dermen, 1990) was chosen for this measure as it is suitable for students in grade 7-16.

One of the more robust findings of ATI research is the degree of interaction between a wide variety of treatments and general ability (Cronbach & Snow, 1977; Koran & Koran, 1984). The interactions that are pertinent to this study involve those concerning the inductive/deductive nature of the learning situation and degree of structure of the task. Inductive methods favor higher ability students, while deductive methods favor lower ability students (Koran, 1971;

Koran & Koran, 1979). The learning task used in this study presented a concept attainment task in an inductive format, so it is reasonable to propose an interaction between task performance and general ability.

The structure of a task also interacts with general ability, with low structure benefitting higher ability students. High structure is more beneficial for low ability students (Cronbach & Snow, 1977; Snow & Lohman, 1984). The present study involves a highly structured learning strategies instructional program. According to Snow & Lohman (1984), this type of study can interfere with high ability students while benefiting low ability students. It has been proposed that higher ability students already have a set of effective strategies to draw on in a learning task (Williams, 1993). Given these interactions with teaching method, structure, and ability, it was reasonable to include a measure of ability. Verbal aptitude has been used as an index of general ability (Koran, Koran, & Baker, 1980), so in addition to serving as a measure of verbal ability as described above, the Extended Range Vocabulary Test also served as a index of general ability in this study. The learning task used in the present study was a concept-attainment task. According to Dunham and Bunderson (1969), success in a concept-attainment task could interact with a memory factor. Memory is important in inductive tasks with no structure. Merrill (1974) found that students who scored low on reasoning benefitted from higher structure tasks. Given the potential interaction of memory and structure, an aptitude test for memory was chosen. A visual memory factor was chosen. Visual memory is "the ability to remember the configural,location,and orientation of figural material" (Ekstrom et al., 1990, p. 109). The ultimate goal of the training program was to facilitate concept formation and induction is an important part of concept formation. Therefore, a measure of induction was selected. The test chosen for the induction factor was the figure classification test (Ekstrom et al., 1990).

In summary, ATI research suggested that for a concept-attainment task that involves induction, written directions, objects and differences in structure, aptitudes of induction, verbal ability, and visual memory were appropriate to test for aptitude-treatment interactions.

Summary

This literature review supports the conclusion that there is a solid body of research regarding the effectiveness of metacognitive training studies. These studies have demonstrated that students can be trained to be more effective readers. It also is clear that additional research extending metacognitive training to learning from science objects is desireable, given the emphasis on hands-on learning in science and the lack of empirically tested strategies for learning from objects. Additionally, given the lack of information regarding teacher training and metacognitive strategies, it is important to focus attention on this area. Finally, ATI research provides evidence of potential learner characteristics which may affect the outcome of the training program.

This review suggests several questions that will be addressed by this study. What effect will a metacognitive training program have on the acquisition of science process skills? What effect will a training program have on concept acquisition? What effect will the training program have on increasing student awareness of metacognitive strategies? What affect will learner characteristics have on the effectiveness of the training program?

Hypotheses

Based on the aforementioned research, the following hypotheses were formulated:

1. There is no relationship between the metacognitive training program and the posttest score.

2. There is no relationship between the application task and the posttest score.
3. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and the posttest score.
4. There is no interactive effect of the training program and the application task on the posttest score.
5. The relationship of the aptitudes with the posttest does not vary by metacognitive training.
6. The relationship of the aptitudes with the posstest does not vary by the interaction of metacognitive training and the application task.
7. There is no relationship between the metacognitive training program and the performance on the application task.
8. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and performance on the application task.
9. The relationship of the aptitudes with the application task do not vary by training condition.

CHAPTER 3
METHODOLOGY

Hypotheses

Based on the aforementioned research, the following hypotheses were formulated:

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3. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and the posttest score.
4. There is no interactive effect of the training program and the application task on the posttest score.
5. The relationship of the aptitudes with the posttest does not vary by metacognitive training.
6. The relationship of the aptitudes with the posttest does not vary by the interaction of metacognitive training and the application task.

7. There is no relationship between the metacognitive training program and the performance on the application task.
8. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and performance on the application task.
9. The relationship of the aptitudes with the application task do not vary by training condition.

Subjects

One hundred twenty-two volunteers from a large public university were recruited for this study. They included 105 female and 17 male students. Data was collected over a 6 week period during the summer semester. Students were given an information sheet describing the study and were asked to sign an informed consent release form (Appendix A). Subjects were assigned to one of 4 treatment conditions (Table 3-1). The analysis was conducted on data collected from these 122 subjects.

General Procedures

Students were recruited from undegraduate education

Table 3-1

Design of Study

Aptitude Tests	Group Assignment	Metacognitive Training Program (Soil Activity)	Task (Fish Activity)	Posttest
0	R 1(n=30)	X	X	0
0	R 2(n=32)		X	0
0	R 3(n=30)	X		0
0	R 4(n=30)			0

classes. Subjects were given aptitude measures of induction, verbal comprehension and visual memory. Aptitude measures were administered to all the subjects in a classroom setting prior to participating in the study activities. They were randomly assigned to one of four treatment treatment groups to ensure equivalent groups. Students were then scheduled to report to a classroom at which time they were given the materials appropriate to their assigned treatment group. Students were given directions appropriate to their assigned group. They were told they had 30 minutes to complete the activity and a stop watch was used to time them. They were monitored throughout the session and were given reminders at the 15 and 25 minute marks. At the end of 30 minutes, the materials were collected. They were then either dismissed or given additional materials based on their group assignment, again in the same type of 30 minute timed session per activity. All subjects completed the posttest at the completion of their last activity. Subjects were given a written reminder not to discuss the study activities with their classmates until the data collection stage of the study was completed.

Experimental Design

This study employed a posttest only control group design

(Campbell & Stanley, 1973) with purposive sampling (Popham, 1988) to recruit subjects. Subjects were randomly assigned to treatment groups to assure equivalent groups.

Treatment Conditions

Subjects in Group 1 were given a metacognitive strategies training program which consisted of a written set of strategies (Appendix B), a soil sample activity, a hand lens, a sieve set with directions for its use, and a data sheet (Appendix C). Subjects were given 30 minutes to complete this portion of the treatment, as described above. These students were then given 30 minutes to complete the application task. The application task included a instructions sheet (Appendix D), three dead, fresh fish, a ruler and a hand lens. A data sheet was provided for this activity (Appendix E). Following completion of the task, students were given 30 minutes to complete a 45 question criterion referenced posttest (Appendix F).

2. Subjects in treatment two were given 30 minutes to complete the application task fish activity. Following completion of the task, students were given 30 minutes to complete the criterion referenced posttest.

3. Students in treatment three were given 30 minutes to complete the training program soil activity. They were

then given 30 minutes to complete the criterion referenced posttest.

4. Students in group four were given 30 minutes to complete the criterion referenced posttest.

Instructional Materials

Metacognitive Training Program-Soil Activity

The student training program and data sheet are found in Appendices B and C. Science For All Students (1993) lists "Recommended Practices in Science Instruction". These recommendations strongly endorse an active, hands-on, concept oriented approach to science education. Hands-on activities are not only appropriate for the youngest children, but also for older students who are encountering a concept for the first time. These recommendations are in contrast to what has been described as typical elementary science instruction that includes "occasional teacher demonstrations, periodic reading assignments, and memory-level tests." (Kauchak & Eggen, 1988, p. 44).

A teaching approach consistent with Science For All Students (1993) is engaging students in "making observations and transforming their observations into concepts and generalizations through the process of inference." (Kauchak & Eggen, 1988, p. 45) Involving the students as active participants has the additional benefit of showing them what science is and allows them to improve their scientific process skills.

The most basic science process skill is observation. It is through observations that students acquire the information necessary to make inferences, generalizations and to acquire concepts. As pointed out by Kauchak and Eggen (1988), it is incorrect to assume that all students are good observers. It was appropriate therefore to choose a task for this study which focused on how to help students become better observers and to make appropriate inferences which will lead to improved concept formation.

For the purposes of this study, in order to insure uniformity of presentation, the students in groups 1 and 3 were given written directions and the soil activity. Research indicates that for a program to be effective, students must be told what strategies to use and how, when and why to use them (Palinscar & Brown, 1989). The written component of the training program utilized in this study incorporated these aspects of declarative and procedural metacognitive knowledge. The written program included sentences that told the reader not only what strategies to use but also why, when, and how to use the strategies.

There are two aspects of metacognition that were included in this metacognitive training program, awareness of cognition and regulation of learning strategies. Based on the research regarding the use of questions as an attention focusing device (Hirschi & Screven, 1988), the training program included steps in which the participants were encouraged to ask themselves questions with respect to what they were doing. The metacognitive training program developed for this study included eight steps. They are Explore, Ask, Observe, Review, Explore again, Infer, Evaluate and Reflect. The steps instructed students to explore, ask, observe, explore again and infer encourage students to become aware of their thinking when interacting with objects. The review, evaluate and reflect steps encouraged the students to control the quality of these interactions by helping them to take steps to remedy gaps in their knowledge.

Step 1, which allows undirected exploration, is borrowed from the museum literature concerning learning from objects. Of the several models describing learning from objects reviewed previously, a feature common to all was the importance of an initial period of interacting with the object (Porter & Martin, 1985; Prown, 1982; Rice, 1988; Williams, 1984).

Step 2 instructed the students to ask themselves questions about any prior experiences or knowledge they may have had with the objects. Additionally, it told them to review in their mind what the five senses are. This step was chosen because the importance of activating prior knowledge is well documented in the metacognition literature (Derry & Murphy, 1986; Levin, 1986; Palinscar & Brown, 1989; Pressley et al., 1985), the literature on science learning and preconceived notions (Griffiths et al., 1988; Lawson, 1988; Philips, 1991; Posner, et al., 1982; Zoller, 1990;), and the museum learning literature (Pearce, 1992; Prown, 1982; Taborsky, 1990).

Steps 3,4 and 5 instructed the student to make observations, review them, and then make additional or better quality observations. These steps were chosen given the importance of the process of observation to science learning and the fact that although the most basic of skills, "When first introduced to the process of observation, students may approach it casually or not understand what is being required of them. Most of them have not been encouraged to be careful and conscientious observers...". (Kauchak & Eggen, 1988, p. 116).

During the review stage, the students were asked to check their observations to be sure they had been precise. This step was included due to the report that while precision is an important science goal, in every day life it is not required and students can have difficulties due to this mismatch (Reif & Larkin, 1991). Encouraging students to evaluate the precision of their observations can ameliorate this mismatch by making the need for precision explicit. This step also helped students control their thinking by encouraging them to pause in their explorations and check the adequacy of their thinking.

Students were then instructed to make additional observations. This step accomplished an important goal. According to Schauble and Glaser (1990), students are inclined to stop a science activity too soon, so this step encouraged the students to go back and spend more time with the objects.

Step 6 instructed the students to make inferences and Step 7 instructed them to evaluate them. Inferring is a science process skill crucial to science concept formation. Reif and Larkin (1991) note that this is another area where goals of science are different from everyday goals in that students in everyday life make fewer inferences and that checking the validity of them is of less importance than in science. These steps were added to not only encourage the skill of making inferences but also to help the student control the quality of them through evaluation. Evaluating for logical sense was suggested by Palinscar and Brown (1989).

Finally, Step 8 called on the students to continue to control their thinking about the object by instructing them to integrate the new knowledge gleaned from the interaction with the object into their existing cognitive structures. This step is consistent with Flemimg (1974) and Haller et al. (1988) who encourage learners to compare new information with existing knowledge.

In summary, each of the steps chosen for this training program were picked to satisfy issues in science learning and metacognitive training that have been discussed in the literature. Each step had a specific goal or purpose.

Another important aspect of training programs is the opportunity to practice (Palinscar & Brown, 1989; Schauble et al., 1991). The activity used as the practice component of the training session was an earth science activity with opportunities to make observations and inferences. This practice activity allowed them to apply the strategies to a hands-on geology lesson, chosen to require the use of the basic science process skills of observation and inference but in a context unrelated to the biological application task.

Application Task Description-Fish Activity

The student application task directions and data sheet are found in Appendices D and E. Students in groups 1 and 3 were provided with three fresh, dead fish, a hand lens, and a ruler. They were asked to make a list of observations of each fish. The fish were representatives of different habitats and feeding habits and exhibited significant differences in fin structure, mouth/teeth structure, color and shape. After making observations, the students were then instructed to make a list of as many inferences as possible. Examples of inferences possible in this activity were; a fish with a large mouth and no teeth does not eat other fish, a fish with underdeveloped fins does not use speed to escape. Many inferences regarding habitat, food source, and defense mechanisms were possible. These are all illustrations of the scientific concept of adaptation.

Each subject's list of observations and inferences was scored for quantity of observations, inferences, and the number of senses used to make the observations. In the data analysis, the application task was analyzed both as independent variable to measure the task effect on the posttest score, and as dependent variable to analyze the effect of the training program on the application task as an outcome variable. For reporting purposes, the metacognition training program will be identified as the "soil activity" throughout the remainder of this report. The application task will be identified as the "fish activity".

Measures

Aptitudes

As reviewed earlier, it is important to choose aptitudes based on the processes which the task requires the subjects to use. For the reasons reviewed earlier, study subjects were given aptitude measures of induction, visual memory and verbal comprehension. These aptitude measures were taken from the Kit of Reference Tests for Cognitive Factors (Ekstrom et al., 1990). This Kit of Factor-Referenced Cognitive Tests was developed for experimental factorial research and therefore does not report validity (Koran & Koran, 1980).

The test chosen for the induction factor is the figure classification test. It consists of 2 parts of 14 items each with 8 test figures and takes 8 minutes per part. Reliabilities for this measure range from .74 to .88 (Ekstrom et al.,1990). The visual memory test to be utilized in this study is the shape memory test which consists of 16 items per part and takes 4 minutes for memorizing and 4 minutes for testing. Its reliability is reported to be .68 (Ekstrom et al., 1990). Verbal comprehension measures "the ability to understand the English language" (Ekstrom et al., 1990, p. 163). The Extended Range Vocabulary Test is a 5-choice synonym test consisting of 24 items and takes 6 minutes. Reported reliabilities range from .81 to .89 (Ekstrom et al., 1990).

Posttest

All subjects were given a 45 point criterion referenced written posttest (Popham, 1988) (Appendix F). All questions were based on the concepts presented by the objects and on metacognitive awareness. Content validity was established by four judges. Split-half reliability was calculated to be .71 using the Spearman-Brown formula. The total test consisted of three subtests of 15 points each. Subtest 1 measured knowledge of the scientific process skills of observation and inferences. Subtest 2 measured concept knowledge with respect to adaptations of fish and included a short (5 point) item on transfer. Subtest 3 measured knowledge of the metacognitive strategies used in the training program.

Data Analysis

The data collected were analyzed using multiple regression analysis to determine treatment effects and aptitude treatment interactions. For the purposes of analysis, the independent variables were tests of induction visual memory and verbal comprehension, metacognitive training (soil activity), and the application task (fish activity). The dependent variables were the scores on the criterion written posttest and the application task (fish activity). Criterion referenced subtest scores were observation/inference knowledge, concept acquisition/adaptations and metacognition knowledge. The fish task total score was composed of number of observations, number of inferences, and number of senses used to make observations. Regression analysis was conducted to determine the effects of treatments on the three posttest subtest scores, and on the three fish task subscores.

In summary, it was determined that the post-test only control group design would be the most productive design to teat the hypotheses. The aptitude tests had no relationship to the criterion measures and the sample was sufficiently large to assume true randomization to treatments. Hence, each hypothesis could be tested by focusing on different dimensions of the design using multiple regression analysis.

CHAPTER 4
RESULTS

It will be recalled that the following hypotheses were tested in this study:

1. There is no relationship between the metacognitive training program (soil activity) and the posttest score.
2. There is no relationship between the application task (fish activity) and the posttest score.
3. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and the posttest score.
4. There is no interactive effect of the training program (soil activity) and the application task (fish activity) on the posttest score.
5. The relationship of the aptitudes with the posttest does not vary by metacognitive training (soil activity).
6. The relationship of the aptitudes with the posttest does not vary by the interaction of metacognitive training (soil activity) and the

application task (fish activity)

7. There is no relationship between the metacognitive training program (soil activity) and the performance on the application task (fish activity).
8. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and performance on the application task (fish activity).
9. The relationship of the aptitudes with the application task (fish activity) do not vary by training condition.

These hypotheses were designed to measure the impact of a metacognitive training program on learning from science objects and metacognitive awareness as well as to determine for whom the training program was most effective for. Data collected from 122 undergraduates at a large public institution on were analyzed. A description of the aptitude and outcome measures is followed by an analysis of the results of the outcome measures and interaction effects.

Aptitude Measures

Aptitude measures of induction, visual memory, and verbal ability were administered. Descriptive statistics for these measures are reported in Table 4-1. The induction mean of 113.43 (SD 34.2) compares to reported means of 120.0 (SD 30.0) and 114.9 (SD 27.8) for high school males and females respectively. The visual memory mean of 25.38 (SD 4.5) compares to reported means of 21.4 (SD 4.3) for male Naval recruits. The verbal ability mean of 22.45 (SD 5.96) compares to reported values of 19.7 (SD 6.6) and 20.7 (SD 6.2) for high school males and females. All of the above listed reported means and standard deviations are published in the Manual for Kit of Factor-Referenced Cognitive Tests, (Ekstrom et al., 1976). Aptitude means by treatment condition are reported in Table 4-2. An analysis of variance indicated that there was no significant difference (p=0.05) between treatment groups on these aptitude scores.

Criterion Referenced Outcome Measure

The criterion referenced test used in the study consisted of 45 questions (Appendix F). Three subtests of 15 points each covered knowledge of the basic science skills of observation and inference, concept acquisition (fish adaptations) and metacognitive awareness.

An item difficulty analysis of the posttest, as measured by percent correct on each item, was conducted (Table 4-3). Thirty-three items on the total test resulted

Table 4-1

Aptitude Descriptive Statistics

	n	Mean	SD	Minimum/Maximum	Total Possible
Induction (X1)	122	113.43	34.16	37-189	224
Visual Memory (X2)	122	25.38	4.48	8-32	32
Verbal Ability (X3)	122	22.45	5.96	8-40	48

Table 4-2

Aptitude Data by Treatment Condition

	Induction			Memory			Verbal Ability		
Group[a]	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	30	123.63	32.35	30	26.37	3.75	30	20.73	5.11
2	32	107.41	34.02	3[illegible]	26.53	3.87	3[illegible]	24.59	5.48
3	30	114.97	34.23	30	24.23	4.95	30	22.17	6.64
4	30	108.13	35.13	30	24.30	4.93	30	22.17	6.13

Group[a] 1 = training program and application task
2 = application task only
3 = training program only
4 = control

Table 4-3

Criterion Referenced Posttest Item Difficulty and Split half Reliability

Item Difficulty	Total Correct	Subtest 1	Subtest 2	Subtest 3
0.91-1.0	4	3	0	1
0.81-.90	5	2	1	2
0.71-.80	12	9	3	3
0.61-.70	5	1	3	5
0.51-.60	3	0	3	0
0.41-.50	3	0	3	0
0.31-.40	4	0	1	3
0.21-.30	4	0	3	1
0.11-.20	5	0	0	0
0.00-.10	4	0	1	0
TOTAL	45	15	15	15
Split half reliability	0.71	0.69	0.53	0.64

in a percent correct rate of 0.50 or higher and 4 items had a percent correct rate of 0.90-1.0. Only 12 items resulted in a percent correct score lower than 0.50. The subtests varied in degree of difficulty. Subtest 1 had no items ranked below 0.61-.70 and three items ranked 0.91-1.0. This subtest measured knowledge of the science process skills of observation and inference, and the item difficulty analysis indicates that this group of subjects had a high level of knowledge regarding these skills.

The second subtest measured concept acquisition, in this case the concept of adaptations of fish based on structure. This subtest had a higher degree of difficulty. In this subtest, 8 out of the fifteen items had a percent correct rate of 0.50 or less.

Subtest 3 measured metacognitive knowledge and the majority of items (11) ranked above the 0.60 percent correct rate. This group had an overall high level of metacognitive awareness, as measured by this instrument.

Split-half reliability was calculated for both the total posttest as well as for the three subsets using the Spearman-Brown formula and are reported in Table 4-3. Mean scores on the total test and the subtests by treatment group are reported in Table 4-4.

Table 4-4

Posttest Means by Treatment Group

	Total Score		Subtest A		Subtest B		Subtest C	
Group[a]	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1 n=30	29.97	3.98	12.53	2.3	6.83	1.97	10.6	2.3
2 n=32	28.94	4.05	11.94	2.40	8.47	1.98	8.53	2.10
3 n=30	26.50	5.37	11.83	2.61	5.2	2.25	9.47	3.01
4 n=30	26.23	2.89	11.77	2.89	5.3	2.2	9.17	2.60

Group[a] 1 = training program and application task
2 = application task only
3 = training program only
4 = control

For the total posttest, Group 1 scored significantly higher than Groups 3 (p=.01) and 4 (p=.00). There were no differences between groups on Subtest 1. On Subtest 2, Group 1 scored lower than Group 2 (p=.01), but higher than Groups 3 (p=.02) and Group 4 (p=.03). Group 2 scored higher than both Group 3 (p=.00) and Group 4 (p=.00). Finally, on Subtest 3, Group 1 scored higher than Group 2 (p=.01).

The study employed two models for the purposes of regression analysis. In Model 1, the application task (fish activity) is treated as an independent variable and its effect on posttest performance is analyzed. In Model 2, the application task (fish activity) total score is treated as a dependent variable.

Regression analyses were employed using the two models and variables as described in Table 4-5.

Model 1 Regression Analysis

Model 1 tested for treatment effects on the criterion referenced posttest. Hypotheses related to model 1 are:

1. There is no relationship between the metacognitive training program (soil activity) and the posttest score.
2. There is no relationship between the application task (fish activity) and the posttest score.

Table 4-5

Regression Analysis Variables

Model 1:

Independent Variables

Aptitudes

X1 = Induction (Induct)
X2 = Visual Memory (Memory)
X3 = Verbal Ability (Verbal)

Treatments

X4 = Metacognitive Training Program (Train) 0=no 1=yes
X5 = Application Task (Task) 0=no 1=yes

Dependent Variables

Y1 = Total Posttest (Posttest)
Y11 = Subtest 1 (Testone) (observation/inference)
Y12 = Subtest 2 (Testtwo) (concept acquisition)
Y13 = Subtest 3 (Testthre) (metacognition knowledge)

Model 2:

Independent Variables

Aptitudes

X1 = Induction (Induct)
X2 = Visual Memory (Memory)
X3 = Verbal Ability (Verbal)

Treatments

X4 = Metacognitive Training Program (Train) 0=no 1=yes

Dependent Variables

Y2 = Application Task Total Score (Tasktota)
Y2A = Subtask A (# of observations) (Observs)
Y2B = Subtask B (# of inferences) (Infers)
Y2C = Subtask C (# of senses used) (Senses)

3. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and the posttest score.
4. There is no interactive effect of the training program (soil activity) and the application task fish task) on the posttest score.
5. The relationship of the aptitudes with the posttest does not vary by metacognitive training (soil activity).
6. The relationship of the aptitudes with the posttest does not vary by the interaction of metacognitive training (soil activity) and the application task (fish activity).

Initial regression analysis of Model 1 failed to find any significant aptitude-treatment interactions, as described in Hypotheses 3, 5 and 6. Therefore, the aptitude interaction variables were removed from subsequent analyses. The training program by application task interaction was examined as part of this investigation. Regression analyses results for total posttest follow.

Total Posttest

Hypotheses relating to performance on the criterion referenced posttest are:

1. There is no relationship between the metacognitive training program (soil activity) and the postscore.
2. There is no relationship between the application task (fish activity) and the posttest score.
4. There is no interactive effect of the training program (soil activity) and the application task (fish activity) on the posttest score.

The regression analysis for the total model, reported in Table 4-6, was significant (F=3.18, p=.01). Findings were insignificant (T=0.18, p=.86) with respect to Hypothesis 1. The metacognitive training program (soil activity) was not significantly related to performance on the criterion referenced posttest.

The data regarding Hypothesis 2 indicated that the application task (fish activity) was significantly related to the total posttest score (T= 2.42, p=.02). Subjects who participated in the application task (fish activity) program performed significantly better on the total posttest than those who did not receive the application task (fish activity).

Hypothesis 4 posited an interaction effect between the training program (soil activity) and the application task (fish activity) with respect to the posttest score.

Table 4-6

Criterion Referenced Posttest Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	24.23	2.74	0.00		8.85	0.00
Induct	0.01	0.01	0.09	0.92	0.95	0.86
Memory	0.06	0.09	0.09	0.90	0.65	0.52
Verbal	-0.03	0.90	-0.04	0.93	-0.41	0.86
Train	0.20	1.08	0.02	0.49	0.18	0.86
Task	2.65	1.08	0.95	0.48	2.42	0.02*
Train*Task	0.56	1.54	0.05	0.32	0.36	0.72

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	334.36	6	55.73	3.18	0.01*
Residual	2015.98	115	17.53		

*Significant findings based on p≤0.05

The regression results for this interaction were not significant (T=.36, p=.72). The aforementioned findings indicate that there was no significant interaction effect between the metacognitive training program (soil activity) and the application task (fish activity)and the posttest score.

Subtest Regression Analysis

The criterion referenced posttest consisted of three subtests, as described above. Regression analysis was conducted on the three subtests. Results are reported below.

Subtest 1

The regression analysis performed on Subtest 1 is reported in Table 4-7. The full model regression analysis was not significant (F=1.54, p=.18). The induction test results yielded a T score of 1.97 (p=.05). Induction ability is positively related to performance on Subtest 1 (observation/inference knowledge).

Subtest 2

Subtest 2 regression analysis results as reported in Table 4-8 are significant (F=8.82, p=.00). Participation in the application task (fish activity) was significantly related to performance on Subtest 2 (concept acquisition

/fish adaptations) (T= 5.76, p=.00). A negative interaction between participation in the training program (soil activity) and the application task (fish activity) was significant (T=-2.14, p=.03). This interaction is illustrated in Table 4-9.

When the application task (fish activity) is provided, students in the no training program (soil activity) group performed better on Subtest 2 than those who participated in both the training program (soil activity) and the application task (fish activity). When the application task (fish activity) is not provided, the training program does not affect performance on Subtest B.

Subtest 3

Regression analysis results of Subtest 3 (metacognition knowledge) are listed in Table 4-10. This model was not significant (F=1.90, p=.09).

Application Task Outcome Measure

As previously described, this study included an application task (fish activity) as described in Chapter 3. This task required subjects in groups 1 and 2 to generate observations and inferences based on a study of three fish and write them on a date sheet provided. These data sheets were scored by an independent scorer who tallied the total application task score by adding the number of observations

Table 4-7

Posttest Subtest 1 Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	8.55	1.52	0.00		5.63	0.00
Induct	0.11	0.04	0.09	0.32	1.97	0.05*
Memory	0.05	0.05	0.11	0.90	1.15	0.25
Verbal	0.02	0.04	0.05	0.93	0.57	0.98
Train	-0.00	0.65	-0.00	0.49	-0.03	0.98
Task	0.00	0.61	0.00	0.48	0.00	0.00
Train*Task	0.55	0.85	0.09	0.32	0.58	0.56

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	48.91	6	8.15	1.51	0.18
Residual	619.06	115	5.38		

- Significance is based on $p \leq 0.05$

Table 4-8

Posttest Subtest 2 Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	5.45	1.38	3.96		3.96	0.00
Induct	-0.00	0.01	-0.05	0.92	-0.56	0.58
Memory	0.05	0.01	0.92	0.92	1.04	0.30
Verbal	-0.04	0.03	-0.14	0.93	-1.26	0.21
Train	-0.07	0.01	-0.02	0.48	-0.14	0.89
Task	3.16	0.55	0.64	0.48	5.76	0.00
Train*Task	-1.66	0.78	-0.29	0.32	-2.14	0.03*

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	234.02	6	39.00	8.82	0.00*
Residual	508.45	115	4.42		

*Significant findings based on p≤0.05

Table 4-9

Interaction of Application Task and Training Program for Subtest 2

		Participation in Training Program	
		No	Yes
Participation in Application Task	No	Adjusted Mean = 5.82	Adjusted Mean = 5.75
	Yes	Adjusted Mean = 8.98	Adjusted Mean = 7.25

Table 4-10

Posttest Subtest 3 Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	10.23	1.67	0.00		6.14	0.07
Induct	0.29	0.01	0.22	0.92	0.22	0.82
Memory	-0.05	0.06	-0.03	0.96	-0.83	0.44
Verbal	-0.01	0.01	-0.01	0.93	-0.16	0.84
Train	0.29	0.66	0.06	0.49	0.43	0.67
Task	-0.52	0.61	-0.10	0.96	-0.78	0.44
Train*Task	1.72	0.91	0.29	0.32	1.84	0.07

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	73.71	6	12.29	1.89	0.09
Residual	746.12	115	6.49		

(Subtask A), number of inferences (Subtask B) and number of senses used to make the observations (Subtask C). Interrater reliability was established at .98. Application task (fish activity) means by treatment group are reported in Table 4-11.

Model 2 Regression Analysis

Total Application Task Score

Hypotheses related to Model 2 are:

7. There is no relationship between the metacognitive training program (soil activity) and the performance on the application task (fish activity).
8. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and performance on the application task (fish activity).
9. The relationship of the aptitudes with the application task (fish activity) do not vary by training condition (soil activity).

The regression analysis of Model 2 was not significant at the p=.05 level (F=1.82, p=.10) (Table 4-12). Hypothesis 7 was investigated and no significant relationship between the metacognitive training program (soil activity) and the

Table 4-11

Application Task Means by Treatment Group

	Total Score		Subtest A		Subtest B		Subtest C	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1 n=30	46.83	16.16	37.30	14.82	7.33	4.44	2.20	.96
2 n=32	54.25	14.84	43.97	13.79	8.28	5.79	2.00	.57

Table 4-12

Application Task Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	18.30	22.31	0.26		0.82	0.42
Induct	0.12	0.08	0.26	0.05	1.49	0.14
Memory	0.34	0.71	0.26	0.53	0.49	0.63
Verbal	0.56	0.51	0.26	0.46	1.49	0.08
Train	14.34	33.71	0.46	0.01	0.49	0.64
Induct*Train	-0.27	0.13	-1.14	0.05	-2.13	0.04
Memory*Train	0.20	1.12	0.17	0.02	0.17	0.86
Verbal*Train	0.34	0.76	0.24	0.05	0.45	0.66

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	2915.58	7	416.51	1.82	0.10
Residual	12334.31	54	228.41		

application task (fish activity) score was found (T=.43, p=.67). Hypothesis 8 concerned the relationship between the aptitude measures and the application task (fish activity) and no significant relationships were determined.

A significant interaction was found with respect to Hypothesis 9. The induction aptitude measure and participation in the training program (soil activity) interacted with respect to performance on the application task (fish activity) (T=-2.13, p=.04). Induction ability was negatively related to training program (soil activity) participation. Subjects who scored low on the induction measure performed better on the application task (fish activity) when exposed to the training program (soil activity), while subjects who scored high on the induction measure performed better on the outcome measure when in the no training program (soil activity) condition. This relationship is illustrated in Figure 4-1.

Subtasks Regression Analysis

The application task (fish activity) consisted of three subtasks, the number of observations (Subtask A), number of inferences (Subtask B) and number of senses used to make the observations (Subtask C). Regression analysis was conducted on the three subtasks. Results are reported below.

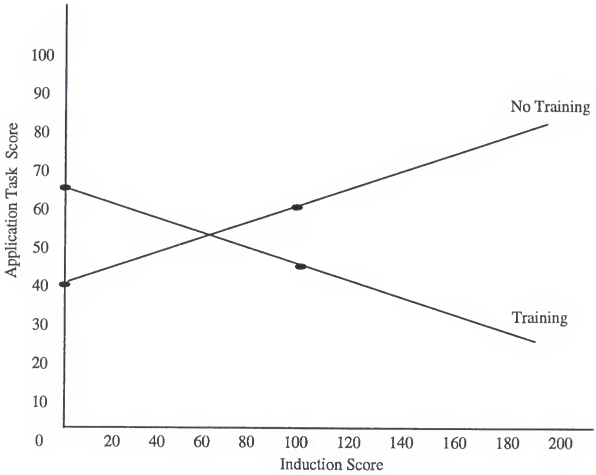

Figure 4-1. Two-way interaction between participation in the training program and participation in the application task for Application Task score.

Subtask A

The regression analysis on Subtask A (observations) is reported in Table 4-13. The full model was not significant (F=1.64, p=.15). The interaction between the induction aptitude and participation in the training program (soil activity) had an F score of -1.97 with a corresponding p value of .05. Students who scored low on the induction measure performed better on Subtask A when given the training program (soil activity). Conversely, students who scored high on the induction measure preformed better on the subtask when in the no-training (soil activity) condition. This interaction is illustrated in Figure 4-2.

Subtask B

The regression analysis of Subtask B (inferences) yielded no significant effects (F=.65, p=.72). There were no significant relationships between the independent variables and performance on Subtest B (Table 4-14).

Subtask C

Regression analysis results for Subtask C (senses) are reported in Table 4-15. The regression model was not significant (F=.90, p=.51). There were no relationships between the independent variables and performance on Subtask C (Table 4-15).

Table 4-13

Application Subtask A Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	6.58	20.76	0.00		0.32	0.75
Induct	0.12	0.08	0.27	0.48	1.52	0.13
Memory	0.41	0.66	0.11	0.53	0.63	0.53
Verbal	0.57	0.47	0.22	0.46	1.20	0.24
Train	21.68	31.38	0.75	0.01	0.69	0.49
Induct*Train	-0.24	0.12	-1.07	0.05	-1.97	0.05
Memory*Train	0.03	1.04	0.03	0.02	0.03	0.97
Verbal*Train	0.01	0.71	0.01	0.05	0.02	0.99

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	2266.53	7	323.79	1.64	0.15
Residual	10689.35	54	197.95		

- Significance is based on $p \le 0.05$

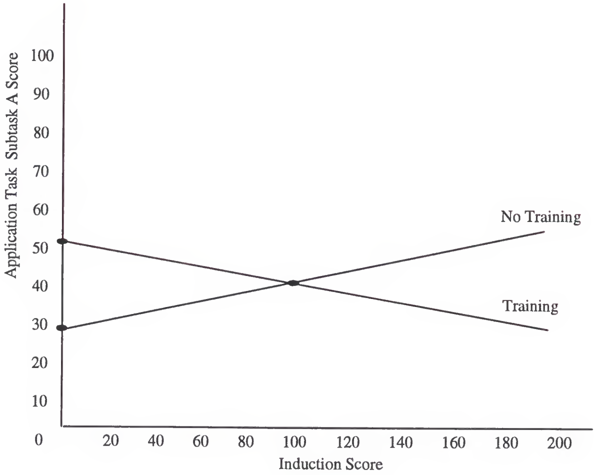

Figure 4-2. Two-way interaction between participation in the training program and participation in the application task for Application Subtask A score.

Table 4-13

Application Subtask A Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	6.58	20.76	0.00		0.32	0.75
Induct	0.12	0.08	0.27	0.48	1.52	0.49
Memory	0.41	0.66	0.11	0.53	0.63	0.53
Verbal	0.57	0.47	0.22	0.46	1.20	0.24
Train	21.68	31.38	0.75	0.01	0.69	0.49
Induct*Train	-0.24	0.12	-1.07	0.05	-1.97	0.05
Memory*Train	0.03	1.04	0.03	0.02	0.03	0.97
Verbal*Train	0.01	0.71	0.01	0.05	0.02	0.99

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	2266.53	7	323.79	1.64	0.15
Residual	10689.35	54	197.95		

- Significance is based on $p \leq 0.05$

Table 4-15

Application Subtask C Regression Analysis Results

Variable	Coefficient	STD Error	STD Coef	Tolerance	T	P(2 Tail)
Constant	1.19	1.16	0.00		1.02	0.31
Induct	-0.00	0.00	-0.05	0.05	-0.07	0.79
Memory	0.04	0.01	0.19	0.53	1.10	0.28
Verbal	-0.01	0.03	-0.04	0.46	-0.20	0.84
Train	-0.12	1.76	-0.08	0.01	-0.07	0.95
Induct*Train	-0.00	0.01	-0.12	0.05	-0.21	0.84
Memory*Train	0.03	0.55	0.55	0.02	0.55	0.59
Verbal*Train	-0.02	0.04	-0.24	0.05	-0.42	0.67

Analysis of Variance

Source	Sum-Of-Squares	DF	Mean-Square	F-Ratio	P
Regression	125.47	7	17.92	0.65	0.72
Residual	1499.58	54	27.77		

- Significance is based on $p \leq 0.05$

Summary

The following hypotheses were tested using multiple regression analysis.

Model 1

Hypothesis 1. There is no relationship between the metacognitive training program (soil activity) and the posttest score.

Finding 1. Failure to reject. Based on this analysis, there is no relationship between the metacognitive training program (soil activity) and the posttest score.

Hypothesis 2. There is no relationship between the application task (fish activity)and the posttest score.

Finding 2. Based on the analysis reported, this hypothesis is rejected. Participation in the application task (fish activity) is positively related to performance on the total criterion referenced posttest.

Hypothesis 3. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and the posttest score.

Finding 3. Failure to reject. There is no relationship between any of the examined aptitudes and the posttest score.

Hypothesis 4. There is no interactive effect of the training program (soil activity)and the application task (fish activity)on the posttest score.

Finding 4. Failure to reject. There is no interactive relationship between the training program (soil activity)and the application task (fish activity)with respect to the posttest.

Hypothesis 5. The relationship of the aptitudes with the posttest does not vary by metacognitive training.

Finding 5. Failure to reject. There is no relationship between the aptitudes and the posttest with respect to metacognitive training.

Hypothesis 6. The relationship of the aptitudes with the posttest does not vary by the interaction of metacognitive training (soil activity)and the application task (fish activity).

Finding 6. Failure to reject. The relationship between the aptitudes with the posttest does not vary by the interaction of metacognitive training (soil activity)and the application task (fish activity).

Model 1 Subtests Results

Subtest 1 - There was a failure to reject Hypothesis 3 when the relationship between the aptitudes of verbal comprehension, induction and visual memory were tested for the total posttest score. A subsequent analysis of the subtests however, revealed a positive relationship between induction ability and performance on Subtest 1.

Subtest 2 - This follow-up analysis revealed that participation in the application task (fish activity) was significantly related to performance on Subtest 2. Also, the interaction between participation in the training program (soil activity) and the application task (fish activity) was significant with respect to the score on Subtest 2. Subjects in the no training condition performed better on Subtest 2 than subjects in the training condition (soil activity) when exposed to the application task (fish activity).

Subtest 3 - There were no significant findings with respect to Subtest 3.

Model 2

Hypothesis 7. There is no relationship between the metacognitive training program (soil activity) and the performance on the application task (fish activity).

Finding 7. Failure to reject. There is no relationship between the metacognitive training program (soil activity) and the performance on the application task (fish activity).

Hypothesis 8. There is no relationship between the aptitudes of verbal comprehension, induction and visual memory and performance on the application task (fish activity).

Finding 8. Failure to reject. There is no relationship between the measured aptitudes and performance on the application task (fish activity).

Hypothesis 9. The relationship of the aptitudes with the application task (fish activity) do not vary by training condition.

Finding 9. Based on the analysis, this hypothesis is rejected. There is a negative relationship between induction ability and training program (soil activity) with respect to performance on the application task (fish activity). Subjects who scored low on the induction measure performed better on the application task (fish activity) when exposed to the metacognitive training program (soil activity), while subjects who scored high on the induction measure preformed better in the no training condition.

Model 2 Subtasks Results

Subtask A- A follow-up analysis of the application subtasks was conducted. This examination revealed a significant negative interaction between induction and training with respect to the score on Subtask A.

Subtask B- No significant relationships were found with respect to Subtest B.

Subtest C- No significant relationships were found with respect to Subtask C.

CHAPTER 5
DISCUSSION AND IMPLICATIONS FOR FUTURE STUDY

Two critical issues in the literature formed the rationale for this study. The first issue was that attempts to teach science which focused on hands-on activities had mixed results at best (Linn, 1986; Pressley, et al., 1987; Watson & Konicek, 1990). The literature supports the contention that children do not spontaneously exhibit the skills necessary to successfully derive meaning from science objects (Reif & Larkin, 1991; Schauble et al., 1991). Often students confuse understanding with producing effects and engage in activities without understanding (Schauble et al., 1991). They are content with action and do not acquire the specific skills desired (Linn, 1986). Reif and Larkin (1991) pointed out that students do not use the degree of precision and consistency which are required in science. Furthermore, although inferences are critical to scientific processes, students make fewer inferences in everyday life and do not make adequate inferences when engaged in scientific activities. Schauble et al. (1991) believe that children tend to search incompletely and unsystematically. Given the current emphasis on hands-on science learning it is critical that techniques are developed to address these shortcomings in students' ability to learn from objects.

The second issue is that even when students are taught the skills necessary to learn from objects, it is uncertain that they will spontaneously use them. Linn (1986) found that students did not use "metareasoning" skills and concluded that unless discovery learning is coupled with "metareasoning" instruction, learning may not take place. Schauble and Glaser (1990) also showed that students do not exhibit metacognitive awareness of the requirements of an experimental task and tend to stop too soon. Students do not spontaneously ask metacognitive questions of themselves, and "there is scant opportunity in the classroom to practice these skills and to consider these questions." (Schauble et al., 1991, p. 879.)

Given this lack of science object learning skills and a corresponding lack of metacognitive awareness with respect to science learning the main purposes of this investigation were to

1. develop a metacognitive strategy training program that is designed specifically for hands-on science activities;
2. to examine the effects of this metacognitive training program on concept acquisition;
3. to examine the effects of this metacognitive training program on metacognitive awareness;

4. to investigate the interaction of learner characteristics with the effectiveness of the training program.

Significant regression analysis results will be discussed first, followed by non-significant results.

Model 1

Model one tested for relationships between the independent variables and the criterion referenced posttest. Also, interactions between the independent variables and the posttest subtests were analyzed. The first significant main effect was that participation in the application task (fish activity) was positively related to posttest score. Participation in the application task (fish activity) was also positively related to the score on Subtest 2. Subjects who were exposed to the application task (fish activity) scored significantly higher on the total posttest as well as on Subtest 2. As mentioned earlier, Subtest 2 was designed to measure the ability of subjects to learn the concept of adaptations in fish. Therefore, the positive effect of participation in the application task (fish activity) is an indication that subjects were able to acquire this concept as measured by the posttest.

The success of the application task (fish activity) in facilitating the acquisition of basic science skills and concept acquisition can be explained by reviewing the learning and memory model illustrated in Fig 2-1. As noted in this model, concept learning is dependent on attention, and curiosity plays an important role in eliciting and maintaining attention (Koran & Longino, 1983). The application task (fish activity) used in this study incorporated a variety of features designed to evoke and focus attention. First, as discussed on Chapter 2, the museum literature indicates that a hands-on experience is more likely than a non-participatory activity to attract and hold an individual's attention (Koran et al., 1983). This task was presented in a hands-on mode. Secondly, the application task consisted of three fish which differed significantly in appearance. A laboratory experience with fresh biological specimens was a sufficiently novel and incongruous experience for these students that their curiosity was sufficiently elicited. The fact that the three fish were significantly different in appearance maintained the subjects' attention as they were instructed to make observations of all three. This is consistent with the literature that describes novelty and incongruous events as stimuli characteristics necessary to evoke curiosity (Koran & Koran, 1983). Finally, the specific directions regarding data recording were highlighted in yellow to focus the students' attention on the task recording requirements.

In addition to the attention and curiosity issues, an additional feature of the study facilitate the encoding and subsequent retrieval of information by these subjects. Application task (fish activity) participants were presented with simple investigative tools along with the objects to encourage an exploration involving multiple sensory channels. This opportunity to process the activity through more than one sensory mode facilitated the acquisition of information from the objects (Koran et al., 1984).

In summary, the ability of the task to evoke curiosity, focus and maintain attention, and allow for multi-channel processing of information provided the prerequisites necessary for the successful encoding, storage and retrieval of the information regarding the concept of adaptations in fish.

Several significant effects were determined when the individual subtests were analyzed. A positive relationship between the aptitude of induction and Subtest 1 score was determined. Subtest 1 included the ability to identify and generate inferences. Induction has been referred to as a "synthesizing process" by Wardell (as cited in Ekstrom et al., 1976, p. 79). Subjects are required to "discover rules that explain things" (Ekstrom et al., 1976, p. 79), an ability usedin drawing inferences from observations. It was identified as a processing skill needed to complete the study tasks, and in the case of Subtest 1, it was positively related. In this study, inductive ability was discretely related to the posttest, as verbal ability and visual memory were not related. The lack of a relationship between performance and verbal ability is contrary to previous findings reported by Cronbach and Snow (1977).

An interaction between the metacognitive training program (soil activity) and the application task (fish activity) was determined when the subtests were analyzed. This follow-up analysis revealed a negative interactive effect of the training program (soil activity) and the application task (fish activity) with respect to Subtest 2. Subjects who completed only the application task (fish activity) performed better on Subtest 2 than subjects who participated in both the training program (soil activity) and the application task (fish activity). As mentioned previously, Subtest 2 measured concept acquisition and the ability to generate inferences from concrete objects. This finding contradicts the expectation that subjects who participated in the training program (soil activity) would perform better on the application task (fish activity) by virtue of gleaning a benefit from the training. Failure to find this result may be due to the study design. Subjects in the application task (fish activity) only group (Group 2) completed the task and posttest in consecutive 30 minute sessions. The training program (soil activity) - application task (fish activity) group (Group 1) completed the two activities and the posttest in three consecutive 30 minute sessions. Subjects in Group 1 may have performed lower than Group 2 due to fatigue and lowered motivation. This is consistent with a report that as task demands increase, less effort is invested (Foster, 1993). Also, it has been shown that more exploratory behavior occurs in the beginning of an activity than later (Vliestra, 1978), further indication that subjects who completed the training program (soil activity) prior to the application task (fish activity) may not have engaged in as much exploration with the second activity as those who only had the second task to complete. Group 1 therefore may have spent less time on what was their second study activity (the application task) than Group 2 for which the application task (fish activity) was their first study activity. This would explain why subjects in the no training program group scored higher than the training program (soil activity) group. Although not collected in the present study, future studies could include a time measure as an indicator of effort to determine if this was a factor in these results.

Model 2

Two significant aptitude interactions were identified with respect to the application task score as the dependent variable. A negative interaction relationship was found betwen induction and the training program (soil activity) with respect to performance on the application task (fish activity). The application task (fish activity) required the subjects to generate a list of inferences derived from their observations of the objects. As described above, the induction test is a measure of an aptitude to "discover rules that explain things" (Ekstrom et al., 1976, p. 79). Additionally, induction is related to concept formation (Ekstrom et al., 1976). Subjects who scored low on the induction measure performed better on the application task (fish activity) when exposed to the metacognitive training program (soil activity), while subjects who scored high on the induction measure performed better in the no training condition. This aptitude interaction effect is consistent with the connection between ability and structure as described by Cronbach and Snow (1977). High ability students tend to perform better in low structured situations. It is supposed that these students have developed their own learning strategies, and imposing a second structure in a learning task interferes with their performance. In addition to the possibility of interference, other possible reasons for this realtionship are that high ability students are bored and less motivated in high structure situations (Salomon, 1971). On the other hand, students of low ability perform better when given a structure to utilize. In this study, the training program (soil activity) was a highly structured, step-by-step procedure. This program may have interfered with students of high induction ability while the structure aided the performance of the students of lower induction ability. This provides evidence that the training program was effective for individuals who do not have the skills necessary to efficiently extract information from objects.

An examination of the application subtasks revealed an interaction between induction and training with respect to the score on Subtask A. This also describes the same type of negative relationship between the training program (soil activity) and performance on Subtask A based on inductive ability. The explanation of this effect would be the same as described for the total application score. Subtask A (#of observations) required subjects to generate observations and inferences from concrete objects, and the structure of the training program (soil activity) may have interfered with this process for those subjects who were already of high ability in inductive skills. Similarly, the training program may have provided needed structure to help lower ability subjects perform better on this Subtest.

Nonsignificant Findings

Model 1 - There were no significant effects of the training program (soil activity) on the total criterion referenced posttest score and no interaction effects of the training program and the application task with respect to the posttest. The training program (soil activity) provided participants with an eight step program to follow which was designed as a series of questions to encourage a thorough examination of the objects as well as to encourage metacogitive awareness. One explanation for the lack of significant finding is that there was a mismatch between the skills taught in the training program and the measurement instrument. The training program instructed students in procedural skills. The posttest was not a skills performance test, and as such may not have adequately assessed the benefits achieved by participating in the training program. If this were the case, one would expect a an assessment instrument that more closely paralled the skills taught in the training program to produce a different result. In fact this was the case. The application task assessment was a skills performance measure, and in this case a significant effect of the training program was determined.

The lack of a significant finding may also be explained by looking at the item difficulty analysis conducted on the posttest. The overall test was relatively easy for this group of subjects. The content covered in the training program (soil activity) was specifically related to Subtest 1 and Subtest 3. The item analysis indicated that for this study group, both of these subtests were relatively easy. The Control group did not score significantly lower on this section than the groups that received the training program (soil activity), a further indication that these subjects entered the study with a level of metacognitive awareness which precluded a significant training program (soil activity) effect.

Another explanation for the lack of an effect of the training program on the posttest is that the training program lacked strength. The training program (soil activity) may not have met the prerequisites for learning from objects as delineated in the learning memory model of Figure 2-1. The training program (soil activity) was a written model which provided information that was tested in Subtest 1 and Subtest 2. The written program used bold type and highlighted directions to focus attention. The practice activity was a soil sample, provided along with a hand lens and a sieve set. The soil sample was a familiar object to these students and as museum object research has shown, subjects spend less time with familiar objects (Koran & Longino, 1983). As described earlier, the key to eliciting curiosity, and attracting and maintaining attention is to have a novel, complex, or incongruous. It is possible that given the familiarity of a soil sample, a sufficient number of perceptual channels may not have been used and curiosity and attention were not evoked, mitigating the results. In the absence of attention and curiosity, encoding and subsequent retrieval would be significantly hampered, hence the lack of effect of the training program (soil activity).

As mentioned earlier, the training program was a highly structured program. A negative relationship between structure and curiosity has been suggested, in which high structure may inhibit curiosity regarding conceptual content (Huston-stein, Friedrich-Cofer, & Susman, 1977; Jenkins, 1969). Therefore, another possible reason why the training program may have failed to evoke curiosity could be its structure.

No relationship was found between the measured aptitudes and performance on the posttest score. Additionally, no two-way or three-way interactions between the measured aptitudes and the total posttest. Although these aptitudes were chosen based on the processing requirements of the tasks, no effect was detected on the total test. For this study, these aptitude measures were not significantly related to performance on the total test, although several aptitude effects were detected when the subtests were analyzed, as described above.

No interactive effect was found between the training program (soil activity) and the application task (fish activity) with respect to the posttest. Once again, it may be that the lack of power of the training program (soil activity) given the high level of entering metacognitive knowledge or lack of stregnth of the program that precluded a significant finding here.

Model 2- The metacognitive training program (soil activity) and the score on the application task (fish activity). Participation in the metacognitive training program (soil activity) did not improve subjects generation of observations and inferences, or in the number of senses used to make these observations. The skills taught in the training program (soil activity) did not transfer to the second task.

One possible reason the training program (soil activity) did not elicit the desired transfer to the application task (fish activity) is the lack of strength of the program to evoke curiosity and attention thereby meeting prerequisites for learning as described above.

Another potential reason for this result is that the two tasks did not make the same processing demands on the subjects. If there was a mismatch between the processing demands made and practiced during the soil sample activity, and those made by the fish activity, then no transfer of skills would have occurred. The fish activity was chosen due to the rich opportunities to make a variety of inferences regarding function. The soil activity on the other hand, provided fewer opportunities, and as such may not have provided adequate training and practice.

Motivation is another possible explanation for this result. As was described earlier, subjects in the training/application task group were volunteers who were required to complete a 30 minute training program prior to the application task. The training program also required that subjects make extensive observations and inferences, and it is possible that subjects were not motivated to continue the same type of activity for the second hour.

Another explanation for this lack of effect is that the program was not extensive enough. Researchers have determined that effective metacognitive training requires more than 10 minutes of instruction per session and reinforcement, and that several instructional modes is preferable to few (Haller et al., 1988). The current study involved a 30 minute training session that included a practice task and the ability to experience as well as read the steps, but it is possible that even more time with the program and additional practice is necessary to achieve the desired strength of the program.

Finally, in spite of the task analysis which suggested relationships between induction, visual memory, and verbal ability and the application task, no interactions were detected.

Implications and Future Studies

This study showed that students acquired science process skills and conceptual knowledge through participation in a hands-on science activity. The metacognitive training program designed to augment the activity had a negative impact on the this effect. While this metacognitive training program did not have a significant effect on knowledge acquisition, it did play a role in performance on an application task. Students low in induction ability benefitted the most from the training program, while high ability students were hampered by the structure of the program.

Some of the questions raised by the results of this study could be answered if a curiosity instrument was added to the design in future studies. A curiosity measure such as described by Peterson and Lowrey (1972) could be utilized which would provide more specific data regarding the manipulation of the objects as an indication of psychomotor curiosity. A time measure would also yield data that would help elucidate the role of curiosity in affecting these results. This would allow the researcher to identify differences in application task and posttest performance as a function of time spent with the objects (an indicator of attention as well as curiosity behavior).

As reported in Chapter 4, the split-half reliability measure used indicated that the reliability of the posttest was .72 (Spearman-Brown calculation) and was lower on the subtests. Instruments of lower reliability increase the likelihood of a Type 2 error, a finding of non-significance when an effect may actually have occurred (Campbell & Stanley, 1973). The training program (soil activity) by application task (fish activity) interaction (T=1.84. p=.07) effect may have been masked by a Type 2 error due to instrument reliability. Improvements in the posttest in subsequent studies to increase its degree of difficulty for this type of subject group would improve the overall reliability of the study results.

These findings regarding the acquisition of concepts from objects have implications for museum researchers as well as science educators. Clearly, it is possible for visitors to gain information through exposure to concrete objects, just as the subjects in this study acquired knowledge from participation in this object activity. Museum researchers will benefit from continued investigation into the role of training in learning from objects and the role that induction ability might play in that training.

The present study was conducted on a sample of undergraduate college students. The metacognition literature supports the contention that teachers often are not adequately trained in metacognitive issues (Moley et al., 1986; Rohwer & Thomas, 1989) and that they have been left out of the loop in metacognitive training studies (Clift et al. 1990; Rohwer & Thomas 1989). For these reasons, teachers-in-training were used as subjects in the study. However, the rationale for the specifics used in the training program was grounded in the literature that pointed out the shortcomings in younger students with respect to science skills and learning strategies. It is likely that the subjects used in this study had too high a level of entering knowledge on two of the areas taught in the program (science skills of observation and inferences and metacognition) to produce significant results of the training program. A follow-up study with a younger, more naive subject group would provide additional evidence regarding the efficacy of the training program.

Informal observations made by the investigator suggest another feature to add to future object learning studies. In both object activities, subjects were provided with simple science tools; hand lenses, rulers, sieve sets. An unanticipated and therefore not quantified observation was that the vast majority of the subjects did not spontaneously use the tools, including the familiar ones. Although training program (soil activity) participants were provided with sieve set directions, subjects for the most part did not use them until specifically instructed to do so in the training program. Quantification of the use of science tools as related to participation in the training program (soil activity) would be valuable data provided by future studies.

A second unanticipated and unquantified outcome was the reaction to the application task (fish activity) by a large number of subjects. These subjects were all enrolled in education classes and most are anticipating a career in elementary education. The science activity used in this study was to make observations of three fresh, dead, fish procured from a fish market, and make inferences about adaptations based on form, a typical biological science type of activity. Of the 122 students who participated in the study, the overwhelming majority did not pick up the fish in the process of making their observations. This related directly to the quality of the observations, as most were made of the fish lying down on a dissecting tray. A review of the museum literature provides a possible explanation for this observation. The subjects in this study were all undergraduate college students. It has been shown that adults over 18 are reluctant to touch objects in a museum setting, as opposed to children who spontaneously manipulate objects (Koran et al., 1983). According to these researchers, this result can be explained by the fact that while children are developmentally receptive to handling concrete objects, often are required to do so in school, and are reinforced for doing so, adults do not have recent experiences in which the manipulation of objects is appropriate. The reluctance of these future teachers to handle a common biological specimen is an interesting observation that could be investigated further with respect to the preparedness of elementary school teachers to teach biological concepts.

An additional implication of this study is that it is of critical importance for adults to help children learn to become keen observers of their environment and to make appropriate inferences. As the primary teacher of a child, a parent can help the child learn these strategies. Schools can play a role in helping parents learn how to help guide their children in the acquisition of these important life skills.

Given the contemporary focus on hands-on learning of science, refinement and additional studies of programs such as this metacognitive training program would help elucidate the best methods to facilitate object learning through metacognitive strategy training.

APPENDIX A
VOLUNTEER SIGNED CONSENT FORM

This research study is being conducted as a part of a doctoral dissertation which has been reviewed and approved by the University of Florida Institutional Review Board. Subjects volunteering for this study are guaranteed anonymity. The purpose of this study is to explore teaching and learning strategies. Volunteers will be given three aptitude tests, a content test and will participate in a maximum of two science activities during this study. The results of these activities will have no adverse impact on the subjects. There will be no compensation for participating in the study. Participation or non-participation will not affect your grade or class standing.

When you volunteer for this study you will be given a randomly assigned number which you must use throughout the study. You may be asked to participate in sessions lasting no longer than 2 hours total. Please fill out the form below and return to Anne Donnelly.

I hereby acknowledge receiving and reading a copy of the project description and agree to participate in the study.

Student____

Date________________________Phone
Number________________________

I agree to keep all participant information anonymous and confidential.

Researcher____
Anne E. Donnelly

Date______________________________
Phone(wk)392-9191(messages)
(hm)376-2591

APPENDIX B
METACOGNITIVE TRAINING PROGRAM

Read the following:

Metacognitive Training Program

Today you are going to receive a training program that will make you more aware of how you think about objects. These procedures will help you make the most of your observations. Use these procedures any time you are asked to make observations and inferences when viewing science objects.

1. **E**xplore - Spend some time exploring the objects in front of you.

2. **A**sk yourself - have I ever seen this before?
   what do I know about this object?
   what are my five senses?

3. **O**bserve - Make a list of as many observations about the object as you can. Observations are data that you collect using the five senses.

4. **R**eview - Mark each observation to indicate which of the five senses you used to make each. Then check to see if there are at least some observations for each sense. Be sure you do not forget the senses of smell, touch and hearing. (NOTE: DO NOT USE THE SENSE OF TASTE UNLESS INSTRUCTED BY YOUR TEACHER TO DO SO). Have you used available scientific tools? Are the observations precise-if you said "red", does it mean striped or dots? Does "pointy" mean all over or just on the ends?

5. **O**bserve again - Using the information you got from your review, go back and make additional observations using whatever senses or available tools you may have under-utilized the first time. Mark these "secondary observations" on your paper.

6. **I**nfer - Make a list of inferences derived from your observations. Inferences are statements based on observations and are interpretations that may explain or interpret.

7. **E**valuate - Check your inferences. Is each inference based on one or more observations? Do your inferences make logical sense?

8. **R**eflect - Think about your inferences. Are they consistent with what you knew before examining the objects? How does this object compare with other objects you have seen?

The process to follow then is explore, ask, observe, review, explore again, infer, evaluate, and reflect (EAOROIER). Using this technique will improve your ability to make keen observations and inferences. It will help you become more aware of how to explore objects and events and how to control your thinking about them.

Go On To Next Page and Follow the Directions

You will now use this technique to complete the following activity. Before you there are two soil samples. Use **EAOROIER** to make observations and inferences from these samples. You may use the page describing **EAOROIER** during this activity. Make a list of all of your observations. Follow **EAOROIER** and make a list of secondary observations. List your inferences and and revisions and reflections made during the process. You will be required to turn in your initial list of observations, your list of secondary observations, and your list of inferences including any revisions made due to the evaluation and reflection steps.

1. **E**xplore the soil samples.

2. **A**sk - Does this look like anything I've seen before? What do I know about soil?

3. **O**bserve - List as many observations as you can.

4. **R**eview - Mark each with the sense that was used. Did you use smell? Did you touch it? Notice it's texture, moisture? Did you use the sieve set to look at size of particles? Did you use the hand lenses, microscope?

5. **O**bserve again - Using the information from your review, make any additional observations that you can.

6. **I**nfer - List any inferences you can make from you observations. Can you generalize where the soil may have come from?

7. **E**valuate - Check each inference. Do your inferences make sense? Does each relate directly to one or more observations? Are there any observations for which you have not made any inferences? Make any additions or changes to your list now.

8. **R**eflect - Are your inferences consistent with what you already knew? How do they compare with one another? Write down any other thoughts you have on these objects.

At the complextion of this activity, turn in your papers to the investigator.

APPENDIX C
TRAINING PROGRAM DATA SHEET

Subject # ______________

Data Sheet:

Observations: (please number them and put one on a line)

Secondary Observations: (please number them and put one on a line)

LIST INFERENCES ON THE BACK
Inferences: (please number them and put one on a line)

APPENDIX D
APPLICATION TASK DIRECTIONS

Today you will be able to try your hand at making observations and inferences. You must complete the activity individually. The investigator is not allowed to answer any of your questions. At the completion of the activity, please turn your paper in to the investigator. The investigator will then give you another short form to complete. When you complete the second form, please turn that in to the investigator. Thank you for your participation.

In front of you are three fish. Make as many observations as you can. An observation is data that you collect using one of your senses. Record these on your paper. Then make inferences about the fish. Inferences extend the observation to explain what is observed. Use the paper provided to record your inferences. When you have completed the activity, turn your paper in to the investigator.

APPENDIX E
APPLICATION TASK DATA SHEET

Subject # ____________

Subject # ______________

Please answer the following questions to the best of your ability, on the paper provided. The investigator cannot answer any questions. Please turn your completed paper in to the investigator when you are finished. Thank you for your cooperation.

1-6. Look at the drawing below. List six observations based on this drawing.

SUBJECTS WERE SHOWN A DRAWING THAT INCLUDED:
A BOY IN WATER, A TREE WITH A BROKEN BRANCH, THREE SMALL TREES, A GOAT, A TOY BOAT, AND A BICYCLE.

1.

2.

3.

4.

5.

6.

DO NOT RETURN TO THIS PAGE ONCE YOU HAVE GONE ON TO THE NEXT.

7-12. Read the anecdote below and identify the numbered statements as either an observation (O) or an inference (I).

Ms. Jones wanted her class to understand buoyancy, so she brought out a rod to which she had attached seven numbered balloons. The balloons were made of latex rubber and were inflated to the same air pressure. They were all opaque and were the size of a volleyball. "Today, everyone," Ms. Jones began, "we want to try and explain why some of the balloons are sticking up in the air and others are hanging down."

_____ 7. "There are some weights in the balloons hanging down," Meredith suggested.

_____ 8. Jeanne noted, "They're all the same size."

_____ 9. "Every other balloon is standing up," Ryan said.

_____ 10. "The stuff in the balloons sticking up is not the same as in the ones hanging down," said Paul.

_____ 11. "If we let some gas out of each balloon sticking up it will smell funny," said Britta.

_____ 12. "When you let it out, you can see that the gas from the balloons sticking up is green," cried Matthew.

13-15. Make three inferences about the leaves shown below.

SUBJECTS WERE SHOWN A DRAWING OF TWO LEAVES JOINED ON A STEM, ONE OF WHICH HAD TWO HOLES AND A TEAR IN IT

13.

14.

15.

DO NOT RETURN TO THIS PAGE ONCE YOU HAVE GONE ON TO THE NEXT.

16. A feature or habit that helps an animal survive in its habitat is called a(n):
    a. accommodation
    b. adaptation
    c. function
    d. feature

17. A mullet's mouth allows the fish to eat what food source?
    a. sieving small food particles out of the mud
    b. grinding crustaceans
    c. clipping vegetation
    d. eating small fish

18. You could infer from the teeth and mouth of the sheepshead that they:
    a. filter plankton from the water
    b. eat sediments
    c. crush and grind crabs and barnacles
    d. catch and eat large fish

19. Which is an accurate statement about the coloration of the snapper?
    a. it would blend in with murky coastal waters
    b. it would be camouflaged in seaweed areas
    c. it is bright as is typical of many reef fish
    d. it is striped vertically, helping to break up its profile

Use the following letter choices to answer the following questions:

a. yellowtail snapper
b. sheepshead
c. mullet
d. all of the above
e. none of the above

20. Which fish had a streamlined body and forked tail fin to adapt it to move quickly in the water?

21. Which fish exhibited the adaptation of countershading, that is dark on the top and light underneath, thus protecting it from predators?

22. Which fish was flattened to allow it to lie on it's side and blend in with the sand?

DO NOT RETURN TO THIS PAGE ONCE YOU HAVE GONE ON TO THE NEXT.
Use the following letter choices for the next three questions:

a. around coastal pilings and shellfish beds
b. in sandy flats near coral reefs
c. in surf area
d. coastal water and estuaries

Given your inferences about the fish, where would you expect to find:

23. the mullet ____________

24. the sheepshead ____________

25. the yellowtail snapper ________

Use the numbered pictures below to make observations and inferences about form and function. Then answer questions 26-30. (these are not drawn to scale).

SUBJECTS WERE SHOWN A DRAWING OF 5 SKULLS REPRESENTING CARNIVORES AND HERBIVORES

Which skull matches each description?:

26. Eats plants, spends daytime in the water and grazes on land at night _______

27. Eats animals, primarily feeding on carcasses and live prey _________

28. Eats leaves, buds, other plants, active at night ___________

29. Eats termites, other insects, burrows in tunnels for daytime, active at night ______

30. Eats aquatic plants, lives in salt and fresh water ______

DO NOT RETURN TO THIS PAGE ONCE YOU HAVE GONE ON TO THE NEXT.

31. Metacognitive learning strategies help you learn science by increasing your:
   a) understanding of basic science process object skills
   b) hands-on experience with science objects
   c) integrated object science process skills
   d) awareness and control of your thinking about science objects

32. A metacognitive strategy that is useful when learning from objects is:
   a) evaluate your observations
   b) find concrete objects
   c) control all of the variables
   d) report the results of your observations

33. A metacognitive strategy that helps activate prior knowledge is:
   a) carefully observe the object
   b) ask yourself questions about the object
   c) operationally define the object
   d) handle the object

34. Which one of the following is not a metacognitive strategy useful when viewing science objects?
   a) explore the object
   b) make inferences
   c) evaluate responses
   d) experiment with the object

35. A collection of objects and some magnets are placed on your desk during a science lab. Which activity below would not increase your awareness of your thinking about these objects?
   a) make inferences about the magnets
   b) explore the magnets with as many senses as possible
   c) identify appropriate student science outcomes
   d) observe the magnets a second time

36. Given the magnets above, which activity would increase your control of your thinking about magnets.
   a) make inferences about the strength of the magnets
   b) connect your new knowledge about magnets with what you knew before exploring them
   c) make a list of secondary observations about how the magnets work
   d) try each object to see if it is magnetic

DO NOT RETURN TO THIS PAGE ONCE YOU HAVE GONE ON TO THE NEXT.

Use the following answers for questions 37-34.
- a) do my inferences make logical sense?
- b) what do I know about these objects?
- c) are my observations precise?
- d) how do these observations fit with what I knew?

37. What is the first thing you should ask yourself when beginning a science activity?

38. What is the last thing you should ask yourself before you finish a science activity?

39. What do you ask yourself when going through the evaluation step?

In a science class, you are given two different rotting logs and asked to investigate them. Match the following questions and comments you would ask yourself to learn from these logs with the metacognitive strategy you are using at each activity.

_____ 40. Review	A. have I seen a rotting log before?
_____ 41. Reflect	B. did I smell the logs?
_____ 42. Infer	C. is there another thing I notice about the logs?
_____ 43. Ask Yourself	D. is what I've observed about logs today different from what I thought at first?
_____ 44. Observe	E. the first log is from a different tree than the second one
_____ 45. Observe Again	F. does the first log have moss on it?

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Anne E. Donnelly was born in Lakewood, Ohio, on June 22, 1953. Following her graduation from Cleveland Heights High School, Ms. Donnelly attended Ohio Wesleyan University from which she earned her Bachelor of Arts Degree with a major in zoology in 1975. She began her professional career working at the Sapelo Island National Estuarine Research Reserve on Sapelo Island, Georgia, as a research technician, eventually serving as the first Education Coordinator for the Reserve. She earned her Master of Business Administration with a major in finance from Georgia State University in 1975. A love of teaching resulted in a position as a science teacher at Walker High School in Dekalb County, Georgia, and subsequent experience working as a Marine Education Specialist at the University of Georgia Marine Extension Center and Aquarium on Skidaway Island in Savannah, Georgia.

Ms. Donnelly is currently working as the Education Coordinator for the University of Florida Engineering Research Center for Particle Science and Technology. She resides in Gainesville, Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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December, 1996

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